Kennelly Notebook #2

This notebook covers the period July 1889-February 1890. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, transformers, induction coils, insulation, and the carrying capacity of various electrical conductors. In addition, there are notes concerning the technical and commercial development of the Niagara hydroelectric power system and tests of motors for the electric railway, phonograph, and sewing machines. Also included are entries pertaining to the electrochemical treatment of arthritic conditions, Kennelly's account of an accidental electric shock he received, and theoretical notes about physics, electricity, and mathematics. Among the experimenters whose work appears in this book are F. P. Bergh, E. C. Boynton, Albert B. Herrick, and Theodore Lehmann. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "II," "1889-1890," and "T." The book contains 165 numbered pages. Some pages were removed before the book was paginated. Graphs and other items have been pasted into the book.

Missing page number: 108.

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Record Book

of

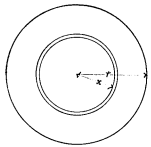
Observations, Calculations, and Data

compiled in the Galvanometer Building

Edison Laboratory Orange N.J.

commenced 28th July 1889
concluded 24th February 1890.

On the Mathematical Theory of the Development of heat in an infinite homogeneous cylindrical conductor freely suspended in air and traversed by a current.



Let r be the radius of the conductor
" ρ " its resistivity at existing temp.
" c " the total passing current.
" J " Joules equivalent 42 megalergs
" K " the thermal conductivity
" D " " density
" σ " " thermal capacity.

Then consider the thermal condition of a corona of unit length and radii x and $x + dx$.

The area of this corona is $2\pi x\,dx$ = also its volume

" current traversing it is $c\,\dfrac{2\pi x\,dx}{\pi r^2} = \dfrac{2cx\,dx}{r^2}$

" resistance of it is $\dfrac{\rho}{2\pi x\,dx}$

" energy developed in it per sec: is $\dfrac{4c^2x^2\,dx^2\,\rho}{2\pi r^4 x\,dx} = \dfrac{2c^2x\,dx}{\pi r^4}$

" heat developed in therms is $\dfrac{2c^2\rho\,x\,dx}{J\pi r^4}$

" flux across the inner surface of the corona is $-2\pi K\dfrac{dv}{dx}x$ per sec

" " " " outer " is $-2\pi(x+dx)K\left(\dfrac{dv}{dx} + dx\dfrac{d^2v}{dx^2}\right)$ per sec

" difference neglecting a quantity of the second order is

$$2\pi Kx\,dx\,\frac{d^2v}{dx^2} + 2\pi K\,dx\,\frac{dv}{dx} = 2\pi Kx\,dx\left(\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx}\right)$$

" total rise of heat in the corona per second is thus

$$2\pi Kx\,dx\left(\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx}\right) - \frac{2c^2\rho\,x\,dx}{J\pi r^4}$$

" heat required to raise the corona $1^\circ C$ is $2\pi x\,dx\,\sigma D$

so that
$$2\pi Kx\,dx\left(\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx}\right) + \frac{2c^2\rho\,x\,dx}{J\pi r^4} = 2\pi x\,dx\,\sigma D\,\frac{dv}{dt}$$

or
$$\frac{dv}{dt} = \frac{K}{\sigma D}\left(\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx}\right) + \frac{c^2\rho}{J\pi^2 r^4\sigma D} \quad \ldots\ldots (1)$$

Now since the permanent state is assumed to have been reached, $\dfrac{dv}{dt} = 0$ and consequently

$$\frac{d^2v}{dx^2} + \frac{1}{x}\frac{dv}{dx} = -\frac{c^2\rho}{JK\pi^2 r^4 \sigma D} = -\varphi \text{ suppose} \quad (2)$$

Then
$$x\frac{d^2v}{dx^2} = -\frac{dv}{dx} - \varphi x \quad (3)$$

$$\therefore\ x\frac{dv}{dx} = -\frac{\varphi}{2}x^2 + a \quad (4)$$

$$\therefore\ \frac{dv}{dx} = -\frac{\varphi x}{2} + \frac{a}{x}$$

$$v = -\frac{\varphi}{4}x^2 + a\log x + b \quad (5)$$

When $x = 0$ $v = V$

$$V = a + b \quad (6)$$

" $x = r$ $v = \theta$

$$\theta = -\frac{\varphi r^2}{4} + a\log r + b$$

$$\therefore\ b = \theta + \frac{\varphi r^2}{4} - a\log r \quad (7)$$

by (4) when $x = 0$ $\dfrac{dv}{dx}$ cannot be ∞ $\therefore a = 0$

but if $a = 0$ when $x = 0$ $a = 0$ always

$$\therefore\ \frac{dv}{dx} = -\frac{\varphi x}{2}$$

$$v = -\frac{\varphi x^2}{4} + b$$

when $x = r$ $v = \theta$ $\therefore \theta = -\dfrac{\varphi r^2}{4} + b$ $\therefore b = \theta + \dfrac{\varphi r^2}{4}$

$$\therefore\ v - \theta = \frac{\varphi}{4}(r^2 - x^2)$$

for $x = 0$ $V - \theta = \dfrac{\varphi r^2}{4}$

$$= \frac{c^2\rho}{4JK\pi^2 r^2}$$

$$= \frac{(c)^2}{(\pi r)^2}\,\frac{\rho}{JK}$$

Also when $x = r$ $\quad \frac{dv}{dx} = -\frac{h\theta}{k}$ because $-k\frac{dv}{dx} = h\theta$

$\therefore$ by (4) $\quad -\frac{rh\theta}{k} = -\frac{\rho r^2}{2} + a$

$$\therefore \quad a = \frac{\rho r^2}{2} - \frac{rh\theta}{k} \qquad (8)$$

So that (5) becomes $\quad v = -\frac{\rho}{4}x^2 + \log_e\left(\frac{\rho r^2}{2} - \frac{hr\theta}{k}\right) + \theta + \frac{\rho r^2}{4} - \log_e\left(\frac{\rho r^2}{2} - \frac{hr\theta}{k}\right)$

$$\therefore \quad v - \theta = \log\left(\frac{x}{r}\right)\left(\frac{\rho r^2}{2} - \frac{hr\theta}{k}\right) - (r^2 - x^2)\frac{\rho}{4} \qquad (9)$$

This expression vanishes when $x = r$

When $x = 0$ $\quad (V - \theta) = +\frac{r^2\rho}{4} + \left(\frac{\rho r^2}{2} - \frac{rh\theta}{k}\right)(1 - \log r)$

$$= \frac{c^2\rho}{4J\kappa\pi^2 r^2} + \left(1 - \log r\right)\left(2T - \frac{rh\theta}{k}\right)$$

where T is the 1st term $\left(\frac{c^2\rho}{2}\right)$

When $r = 1$ (conductor nearly 1" in diam)

$c = 1000$ amps $= 100$ in abs.

$\rho = 2000$ abs w. at temp. supposed to be existing.

$J = 4.2 \times 10^7$

$\kappa = 1.1$ for copper

$\pi^2 = 10$

$h = 6.0 \times 10^{-4}$

$\theta = 50$ abs

we have $\quad 3\left(\frac{1.0 \times 10^4 \times 2.0 \times 10^3}{4 \times 4.2 \times 10^7 \times 1.1 \times 1.0 \times 10^1}\right) - \frac{1 \times 6.0 \times 10^{-4} \times 5.0 \times 10^1}{1.1}$

$$= \frac{6 \times 10^7}{19.5 \times 10^8} - \frac{30 \times 10^{-3}}{1.1}$$

$$= 4 \times 10^{-2} - 3 \times 10^{-2}$$

$$\Rightarrow 1 \times 10^{-2}$$

Or the difference of temperature between the axis and surface of such a conductor would not exceed $\frac{1}{100}$th of one degree Centigrade.

In fact consider this conductor to be enveloped by a cylinder of thickness 1 cm whose thermal conductivity is equal to that of copper (1.1) but whose electrical conductivity is zero, and let the outside surface of this cylinder be maintained at 0°C. Then the total heat developed in unit length of the conductor per second equal

$$\frac{1.0 \times 10^4 \times 2.0 \times 10^3}{4.2 \times 10^7 \times 3.14} = 0.152 \times 10^0 = 1.52 \times 10^{-1}$$

The equivalent surface of the envelope would be roughly $2\pi \times 1.5 = 9.42$ cms: and the thickness would be 1

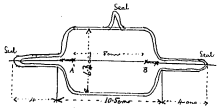
$$\therefore \quad -k\frac{dv}{dx} \times 9.42 = 0.152$$

$$dv = -\frac{0.152}{1.1 \times 9.42} = -0.0147$$

or a little more than $\frac{1}{70}$ of one deg. C

The effect of the augmented distribution and development of heat which varies directly as the radius, is to still further reduce the gradient

Record of test made on the 1st Nov: 88 under my directions by Messrs Bergh + Boynton upon the fusing point of metal wire sealed in exhausted globes.



These globes were blown in the shape indicated that is to say roughly cylindrical. The thickness of the glass varies from 0.015" = 0.038 cm to 0.04" = 0.10 cm but averages about 0.02" = 0.05 cm. in the cylindrical part. The circumference of the cylinder was about 20 cm., and the internal radius consequently about 3.15. Three platinum wires each 0.0125" = 0.032 cm were brought through the seals at the extremities and connected with the wire under test at the points A and B about 8 cm apart. The globes were then exhausted and sealed. A current was then passed through these globes immersed in water contained in a basin and at an observed temperature. The deflection at which luminosity was first reached, and the fusing point were taken. Two globes were prepared for each metal.

Copper wire Diam: 0.0155" = 0.0394 cm.

Res. @ 20°C $= \cancel{\frac{217.5 \times}{275 \times 78.2}} = \cancel{\frac{217.5}{21500}} = \cancel{0.01012}$ " per cm.

$\cancel{= 0.01012 \times 0.0394 =}$

$= \frac{475 \times 0.1}{\cancel{217.5} \times 78.2} = \frac{47.5}{17010} = \frac{1.455}{\cancel{777}} \times 10^{-3}$ " per cm.

$= 1.617 \times 10^{6} \times 1.219 \times 10^{-3} = 1.975 \times 10^{3}$ resistivity at 20°C.

$= 1650$ " 0°C.

Watch deflection at first appearance of luminosity = 1.15 = 5.90 amp.

" platinum red heat 1.24

" cherry " " 1.50

" fusion 1.52 = 7.796 "

At melting point of copper 1054°C = 1328° abs.

by Siemens formula $r_{20} = 0.026577 \times \frac{\sqrt{294}}{\cancel{17.65}} + 0.00311443 \times 294 - 0.29751$

$= 0.4558 + 0.9246 - 0.29751$

$= 1.0829$

$r_{525} = 0.026577 \times \frac{\sqrt{799}}{28.3} + 0.00311443 \times 799 - 0.29751$

$= 0.7518 + 2.512 - 0.2975$

$= 2.9663$

$r_{1054} = 0.026577 \times \frac{\sqrt{1328}}{36.45} + 0.00311443 \times 1328 - 0.29751$

$= 0.9686 + 4.176 - 0.2975$

$= 4.847$

By this reckoning the res: of the wire would be $\frac{1.455 \times 10^{-3} \times 2.9663}{1.0829} = 3.985 \times 10^{-3}$ @ 525°C and $\frac{1.455 \times 10^{-3} \times 4.847}{1.0829} = 6.512 \times 10^{-3}$ @ 1054°C

The energy developed per unit length + time at 525°C was $\frac{5.9^2 \times 3.985 \times 10^{-3}}{4.2} = \frac{3.307}{4.2} = 4.475 \times 10^{-3}$

" " " " " " 1054°C " $\frac{7.8^2 \times 6.512 \times 10^{-3}}{4.2} = \frac{9.45}{4.2} = 2.14 \times 10^{-3}$

" surface of unit length = 3.1416 × 0.0394 = 0.1238

$\therefore x = \frac{0.02207}{500 \times 0.1238} = \frac{3.307 \times 10^{-2}}{6.19 \times 10^{1}} = 0.534 \times 10^{-3} = 5.34 \times 10^{-4}$ for 525°C

$x = \frac{0.0243}{1030 \times 0.1238} = \frac{2.14 \times 10^{-2}}{1.238 \times 1.03 \times 10^{3}} = 0.952 \times 10^{-3} = 9.40 \times 10^{-4}$ for 1054°C.

The second copper wire first became luminous when the Obach deflection was 1·2 and fused when the latter reached 1·5. The temperature of the immersion bath was 21°C. Practically the same results. The following table gives the full particulars

No.	Metal	Diameter in In.	Diameter in Cms.	Inches Area.	Inches Surface	Centimetres Area.	Centimetres Surface	at Commencing Obach	at Commencing Deg. °C	at Commencing Current	at Obach 2·4	at Obach 2·4 Deg. °C	Fusion Current
1	Cu	0·0170	0·0432	0·000227	0·0534	0·00147	0·1360	1·0	21°	5·13	1·30	21°	6·47
2								1·0	21°	5·13	1·32	21°	6·77
3	Ag?	0·0152	0·0386	0·000181	0·0478	0·00117	0·1213	0·90	21°	4·62	0·97	21°	4·98
4											0·97	22°	4·98
5	Cu	0·0155	0·0394	0·000189	0·0487	0·00122	0·1238	1·15	22°	5·90	1·52	22°	7·80
6								1·20	21°	6·16	1·50	21°	7·70
7	Solder	0·0418	0·1062	0·001037	0·1313	0·006689	0·8330				0·93	22°	4·77
8											0·82	21°	4·21
9	Ni	0·0123	0·0312	0·000119	0·0386	0·000760	0·0980	0·31	21°	1·59	0·76	21°	3·90
10								0·52	22°	2·67	0·90	22°	4·62
11	Fe	0·0172	0·0437	0·000232	0·0540	0·00150	0·1373	0·53	23°	2·72	1·34	21·5	6·87
12								0·68	21°	3·49	1·34	21°	6·87
13	Steel	0·0152	0·0386	0·000181	0·0478	0·00117	0·1213	0·42	21·5°	2·15	0·93	21·5	4·77
14								0·47	21·5°	2·41	0·90	21·5	4·62
15	Pt	0·0240	0·0610	0·000452	0·0754	0·00292	0·1916				0·82	19°	4·21
16											0·78	21°	4·00
17	Al	0·0152	0·0386	0·000181	0·0478	0·00117	0·1213	0·88	22°	4·51	0·95	22°	4·87
18								0·87	21°	4·46	1·00	21°	5·13
19	Cd	0·0206	0·0523	0·000333	0·0647	0·00215	0·1643				0·70	22	3·59
20											0·72	20·5	3·60
21	Brass	0·0158	0·0401	0·000196	0·0496	0·00126	0·1260	0·70	19	Gas brought	0·92	19°	4·21
22								0·96	20	4·92			6·57
23	German Silver	0·0172	0·0437	0·000232	0·0540	0·00150	0·1373						
24								1·16	21·5	5·95	1·9		9·75
25	Mg	0·0172	0·0437	0·000232	0·0437	0·00150	0·1373	1·26	21·5	6·46	1·4	21·5	8·72
26								1·66	20·5	8·41	1·85	20·5	9·53

No.	Metal	Length	Deflection	Deflection obs 0·1	Res.	Res per cm.	Resistivity @ temp.	Energy Kg. metres per sec. @ 525°	k @ 525°	k @ fusing temp	fusing temp
1	Cu	6·1	46·2	421·5							
2		6·1	42·4	421·2							
3	Ag?	15·2	1·81	429·2							
4		14·7	1·82·8	239·0							
5	Cu	7·8·2	4·75	417·5	0·1138	$1·455 \times 10^{-3}$	$1·775 \times 10^{-6}$	0·0331	0·0403	0·00053	0·00074
6										0·00224 watt	0·00314 cg
7	Solder	14·8	1·22	419·7						1·186 Watts	3·477 W.B.
8											
9	Ni	6·9	207	390							
10											
11	Fe	14·0	49·35	424·5							
12											
13	Steel	6·2	420	390							
14											
15	Pt	15·0	200	389							
16											
17	Al	40·1	471·5	423·5							
18											
19	Cd	13·8	227·8	423·8							
20											
21	Brass	12·4	487·5	420							
22											
23	German Silver	7·0	480	393							
24											
25	Mg	14·5	393	419·5							

By Preece's tables

Copper wire	0·0155"	would be fused by	20 amps	and were in this case by						7·75
Iron .	0·0172	- - - -	27·5 -	- - - -	- - - -					6·87
Lead .	0·0240	- - - -	8·5 -	- - - -	- - - -					4·20
Aluminium -	0·0172	- - - -	17 -	- - - -	- - - -					5·05
German Silver -	0·0172	- - - -	12·5 -	- - - -	- - - -					9·23

log 1·0077 = 0·0033213 × (525 − 21) = 1·6789752 = log⁻¹ 47·75 − 1 = 46·75
× 0·06858 = 3·0658 = calculated radiation in Watts per sq. cm @ 525°C

= 1·0077 = 0·0033213 × (1054 − 21) = 3·4412329 = log⁻¹ 27·62 − 1 = 2762.
× 0·06858 = 18·106 = calculated radiation in Watts per sq. cm @ 1054°C

Carrying Capacity of Conductors:

A wire of soft copper 0.058" = 0.14732 cms diam (#17 SWG) was suspended somewhat diagonally across the room the length being about 7885 cms. They were fixed about 250 cms above the ground and about 25 cms apart. The Obach galvo. and the grid of full length 0.0499 were included in the circuit. The experiment was arranged for the purpose of ascertaining how far the emissivity was affected by superficial changes on the wire.

Wire #1 was given a slight coating of shellac varnish
" #2 " " solution of Na_2S " copper sulphide by applying
" #3 " " " ~~phosphorus~~ phosphor bronze applied with molasses.
" #4 " brightened by rubbing with emery paper
" #5 left with its usual slightly oxidised surface untouched.

Res. of grid 0.0499

No. of Obs.	Time	Obach	Current	Potente	Current	Mean Potente	Mean Current	Res: of wire at 262.	Mean Res: $\phi\sigma$	Res: per cent. @ 0°C	Resistivity + for cmds
1	11.00	0.215	1.103	0.0325	1.303	0.0287	1.15	0.0851 Ω	0.0773	·9593 x10⁻⁶	1678
2	·10	0.980	5.03	0.1246	4.995	0.1241	4.97		7.73x10⁻²	·9592 x10⁻⁶	
3	·20	2.060 (1)	10.46	0.2614	10.47	0.2611	10.46		7.815 x 10⁻²		
4	·28	3.04 (1)	15.59	0.3960	15.87	0.3974	15.93			Average 1.597 x10⁻⁶	
5	·37	4.04 (1)	20.71	0.5204	20.86	0.5204	20.86				
6	·48	4.68 (1)	24.00	0.6286	25.20	0.6153	24.66				
7	11.00	5.84 (1)	29.95	0.7750	31.06	0.7678	30.77				
8	·14	7.16 (1)	36.72	0.9614	38.54	0.9577	38.39				
9	·20	7.88 (1)	40.41	0.5234	41.96	0.5190	41.61				
10	·37	8.64 (1)	44.31	0.5720	45.87	0.5705	45.74				

0.0280

No. of Obs.	Time	Res: added to wire	Total res. in wire ect.	Res: of wire	$\frac{R}{r}$	Rise of temp. in	Current amperes	Energy per sq. cm.	Emissivity	Temp. air	Res. of 1 cm wire
1	10.55	1940	4650	0.0850	1.00		1.2	1.4648 7.4410⁻⁶		26.1°C.	1.0290x10⁻⁴
2	·55	1950	4660	0.0857	1.001	c.2	5.0	27.07x10⁻⁶ 137.5x10⁻⁶			1.096
3	02 28	2075	4785	0.0881	1.029	7.46	10.5	1.242x10⁻⁶ 6.44x10⁻⁶	8.6 x10⁻⁴		1.127
4	25 27	2260	4975	0.0915	1.069	17.79	15.9	2.85x10⁻⁶ 18.13x10⁻⁶	6.46 x10⁻⁴		1.171
5	31 28	2590	5300	0.0975	1.139	35.8	20.9	5.11x10⁻⁶ 28.9x10⁻⁶	7.45 x10⁻⁴		1.248
6	10.44	2915	5625	0.1035	1.209	53.9	24.7	6.97x10⁻⁶ 41.5x10⁻⁶	7.72 x10⁻⁴		1.324
7	11.00	3400	6100	0.1123	1.312	80.44	30.8	9.36x10⁻⁶ 70.4x10⁻⁶	8.73 x10⁻⁴		1.437
8	·14	4230	6940	0.1277	1.492	126.8	38.4	14.40x10⁻⁶ 127.0x10⁻⁶	9.76 x10⁻⁴		1.634
9	·20	4935	7645	0.1407	1.644	166.0	41.6	31.17x10⁻⁶ 164.4x10⁻⁶	9.68 x10⁻⁴		1.801
10	·37	5500	8210	0.1511	1.766	197.5	45.7	47.79x10⁻⁶ 248.2x10⁻⁶	1.23 x10⁻³		2.26

Shellac

t	Convection assumed for 1 cm.	Total energy per cm	Radiation per cm	Radiation per sq. cm.	Radiation for bright wire	Ratio	Bat. wt	
7.5	0.007	0.0124	0.0054	0.0117	0.00445	2.6	–	
17.8	0.017	0.0216	0.0046	0.00994	0.0102	0.99	–	
35.8	0.038	0.0845	0.0165	0.0356	0.0220	1.62	2	3.24
53.9	0.056	0.1508	0.0248	0.0536	0.0350	1.53	3	4.59
80.4	0.089	0.1363	0.0473	0.1022	0.058	1.76	3	3.52
126.8	0.160	0.2410	0.0510	0.1750			7	11.35
							Mean	1.62

t	Coefficient of convection	Energy per cm	Radiation total	Radiation per sq. cm.	Radiation for a heater two feet long	Ratio radiation/heat	Weight estimated	
1·7	0·102	0·002274	0·00774	0·00159	0·001	1·60	(1)	1·6
8·3	0·108	0·0124	0·00444	0·000508	0·00448	2·98	(2)	3·96
18·3	0·118	0·0245	0·0115	0·02485	0·018	1·91	(3)	5·73
24·2	0·0287	0·05140	0·0253	0·05467	0·017	3·22	(1)	3·22
36·5	0·0366	0·0719	0·0423	0·09114	0·0225	4·05	(1)	4·06
72·4	0·0788	0·1326	0·0538	0·1163	0·051	2·28	(3)	6·84
109·4	0·130	0·2289	0·0959	0·2137	0·087	2·40	(3)	7·20
146·2							14	32·79
							Mean	2·34

t							
2·3	0·0025	0·002274	0·00224	0·00519	0·0013	4·0	
5·8	0·0084	0·01286	0·0039	0·00543	0·0053	1·59	(1) 1·59
18·9	0·0176	0·02945	0·01185	0·0256	0·0113	2·27	(2) 4·54
33·5	0·0332	0·05765	0·02045	0·0442	0·0202	2·19	(3) 6·57
36·9	0·0370	0·05876	0·01976	0·0405	0·0227	1·70	(4) 6·80
70·4	0·0760	0·1322	0·0552	0·1193	0·0447	2·40	(3) 7·20
100·8	0·1170	0·2229	0·1059	0·229	0·0580		13 26·40
134·6							2·05

t	rad. coeff.	Total radiation	Total Energy	Convection
4·1	0·0025	0·001156	0·00276	0·00160
10·6	0·0062	0·00287	0·01253	0·00966
24·5	0·0145	0·00674	0·03036	0·02335
41·5	0·0240	0·0344	0·05761	0·04417
59·8	0·0342	0·0186	0·08462	0·06392
93·6	0·0725	0·0338	0·14090	0·10690

t	rad. coeff.	Total radiation	Total Energy	Convection
4·2	0·0025	0·00116	0·00276	0·00160
11·9	0·0071	0·00329	0·01252	0·00923
25	0·0150	0·006934	0·03011	0·02317
43	0·0270	0·0125	0·05534	0·04288
61·8	0·0425	0·0197	0·08216	0·06246
94·9	0·073	0·0338	0·1410	0·1072

No.	Res. in cat. with wire	Total res. in wire cat.	Res. of wire	$\frac{R}{T}$	Rise of temp.	Current amperes	Res. per cm.	Energy per cm.	Energy per sq. cm.	Thermal per sq. cm.	Emissivity	Temp. cm.	
						C	C^2						
1	1920	4620	0·08525	1·0				1·091 x 10⁻⁶					36·6
2	1950	4660	0·0858	1·0065	1·7	5·0	25	1·098		2·746 x10⁻³	1·415 x10⁻³	8·30 x10⁻³	
3	2070	4780	0·0880	1·032	8·25	10·5	110·3	1·126		1·242 x10⁻²	6·402 x10⁻³	7·76 x10⁻³	
4	2247	4957	0·0913	1·071	18·3	15·9	252·8	1·168		2·952 x10⁻²	1·522 x10⁻²	8·32 x10⁻³	
5	2540	5250	0·0967	1·134	29·2	20·9	436·3	1·237		5·403 x10⁻²	2·786 x10⁻²	9·54 x10⁻³	
6	2775	5485	0·1010	1·185	36·5	24·7	610·1	1·293		7·896 x10⁻²	4·068 x10⁻²	1·33 x10⁻²	
7	3220	5930	0·1092	1·281	72·4	30·8	948·6	1·398		1·326 x10⁻¹	6·836 x10⁻²	9·44 x10⁻³	
8	3880	6590	0·1213	1·423	109·	38·4	1475	1·552		2·289 x10⁻¹	1·180 x10⁻¹	1·08 x10⁻²	
9	4585	7295	0·1343	1·575	148·2	41·6	1731	1·718		2·973 x10⁻¹	1·532 x10⁻¹	1·035 x10⁻²	
10	5120	7840	0·1444	1·690	177·8	45·7	2088	1·888		3·839 x10⁻¹	1·979 x10⁻¹	1·076 x10⁻²	

No.	Res. in cat. with wire	Total res. in wire cat.	Res. of wire.	$\frac{R}{T}$	Rise of temp.	Current amperes	Res. per cm.	Energy per cm.	Energy per sq. cm.	Thermal per sq. cm.	Emissivity	Temp. cm.	
						C	C^2						
1	1900	4610	0·08488	1·0				1·096 x10⁻⁶					34·6
2	1940	4650	0·08562	1·0091	2·3	5·0	25	1·096		2·761 x10⁻³	1·413 x10⁻³	6·17 x10⁻³	
3	2057	4767	0·08778	1·0341	8·8	10·5	110·3	1·123		1·239 x10⁻²	6·381 x10⁻³	7·25	
4	2235	4945	0·09106	1·073	18·8	15·9	252·8	1·165		2·945 x10⁻²	1·518 x10⁻²	8·04	
5	2500	5210	0·09594	1·130	33·5	20·9	436·8	1·228		5·365 x10⁻²	2·746 x10⁻²	8·26	
6	2760	5270	0·09702	1·143	36·9	24·7	610·1	1·242		7·896 x10⁻²	4·068 x10⁻²	1·058 x10⁻²	
7	3160	5870	0·1081	1·273	70·36	30·8	948·6	1·383		1·312 x10⁻¹	6·762 x10⁻²	9·61 x10⁻³	
8	3740	6450	0·1181	1·391	100·8	38·4	1475	1·511		2·229 x10⁻¹	1·149 x10⁻¹	1·114 x10⁻²	
9	4215	6925	0·1275	1·502	129·4	41·6	1731	1·632		2·825 x10⁻¹	1·456 x10⁻¹	1·136 x10⁻²	
10	4710	7420	0·1366	1·610	157·2	45·7	2088	1·749		3·650 x10⁻¹	1·882 x10⁻¹	1·197 x10⁻²	

No.	Res. in cat. with wire	Total res. in wire cat.	Res. of wire	$\frac{R}{T}$	Rise of temp.	Current amperes	Res. per cm.	Energy per cm.	Energy per sq. cm.	Thermal per sq. cm.	Emissivity	Temp. cm.	
						C	C^2						
1	1900	4610	0·08488	1·0				1·086 x10⁻⁶					26·6
2	1977	4685	0·08626	1·0160	4·1	5·0	25	1·104		2·760 x10⁻³	1·423 x10⁻³	3·97 x10⁻³	
3	2115	4825	0·08884	1·041	10·6	10·5	110·3	1·137		1·253 x10⁻²	6·459 x10⁻³	6·49	
4	2335	5045	0·09292	1·095	24·5	15·9	252·8	1·189		3·006 x10⁻²	1·549 x10⁻²	6·32	
5	2645	5355	0·09860	1·161	41·5	20·9	436·8	1·262		5·511 x10⁻²	2·841 x10⁻²	6·84	
6	2970	5680	0·1046	1·232	59·8	24·7	610·1	1·338		8·162 x10⁻²	4·208 x10⁻²	7·04	
7	3575	6285	0·1157	1·363	93·6	30·8	948·6	1·480		1·404 x10⁻¹	7·238 x10⁻²	7·73	
8	4400	7110	0·1309	1·542	139·7	38·4	1475	1·675		2·147 x10⁻¹	1·273 x10⁻¹	9·11	
9	5120	7820	0·1442	1·699	180·1	41·6	1731	1·845		3·194 x10⁻¹	1·646 x10⁻¹	9·24	
10	5670	8380	0·1543	1·818	210·8	45·7	2088	1·974		4·122 x10⁻¹	2·125 x10⁻¹	1·005 x10⁻²	

No.	Res. in cat. with wire	Total res. in wire cat.	Res. of wire	$\frac{R}{T}$	Rise of temp.	Current amperes	Res. per cm.	Energy per cm.	Energy per sq. cm.	Thermal per sq. cm.	Emissivity	Temp. cm.	
						C	C^2						
1	1900	4610	0·08488	1·0				1·086 x10⁻⁶					26·2
2	1977	4687	0·0863	1·0164	4·2	5·0	25	1·104		2·760 x10⁻³	1·423 x10⁻³	3·39 x10⁻³	
3	2110	4820	0·0888	1·046	11·85	10·5	110·3	1·136		1·252 x10⁻²	6·453 x10⁻³	5·45	
4	2345	5055	0·0931	1·097	25·	15·9	252·8	1·191		3·011 x10⁻²	1·552 x10⁻²	6·23	
5	2675	5385	0·0991	1·167	43·	20·9	436·8	1·268		5·538 x10⁻²	2·855 x10⁻²	6·64	
6	3000	5710	0·1052	1·2260	61·8	24·7	610·1	1·347		8·216 x10⁻²	4·235 x10⁻²	6·85	
7	3600	6310	0·1162	1·368	94·8	30·8	948·6	1·487		1·410 x10⁻¹	7·268 x10⁻²	7·67	
8	4625	7355	0·1355	1·596	153·6	38·4	1475	1·734		2·555 x10⁻¹	1·318 x10⁻¹	8·58	
9	5220	7930	0·1460	1·720	185·6	41·6	1731	1·868		3·233 x10⁻¹	1·666 x10⁻¹	8·94	
10	5750	8460	0·1558	1·835	215·2	45·7	2088	1·993		4·162 x10⁻¹	2·145 x10⁻¹	9·97	

Inductance of the large Solenoid of ~~sixteen~~ fifteen layers covered wire.

No. of obs	Date	Section	Observed Res.	Ratio	Capacity on 1000/1000 side	Inductance Secohm	Inductance Kilometer	Mean value Kilometer	Res. of Coil.	Resistance @ 25°C
1	27.7.89	T – II	1.407 ω	1000/10	1.40 f	0.001969	19.69 ω		0.120 ω	
2		II – IV	4.342		1.39 f	0.001865	18.65			
3		T – IV	2.635		2.68 f	0.007062	70.62 ω			
4		T – VI	3.797		3.918	0.014888	148.8 ω			
5		T – VIII	4.905		5.0	0.024553	245.3 ω			
6	29.7.89	T – II	1.421		1.410	0.002003	20.3 ω	20.0		1.304 ω
7		T – IV	2.664		2.640	0.007034	70.34 ω	70.43		2.544 ω
8		T – VI	3.835		3.855	0.014878	147.8 ω	148.3		3.715 ω
9		T – VIII	4.945		4.950	0.024548	244.8 ω	245.0		4.825 ω
10		T – XIII	~~4.867~~	1000/100	0.50	0.024344	243.4			
11		T – X	5.89	-	0.60	0.035334	353.4	353.4 #		5.77 ω
12		T – XII	6.847	-	0.68	0.046657	465.7	465.7		6.73 ω
13		T – XVI	8.647	-	0.820	0.070290	709.0	709		8.53 ω

* The last three measurement are not very accurate.

Comparison of resistances.

July 31st Wednesday

Took a rough comparison of the grid in multiple arc with the 0.01ω standard copy @ 25.5°C. = 0.009675 at that temp. by account.

610ω added to grid.

$$\frac{2730}{3340\,\omega} : 2730 :: 0.01 : 0.009675$$

$x = 0.011184\,\omega$. By account it is $0.0121\,\omega$

Resistance and Inductance of the Speaking Mirror Galvanometer

July 29th Monday.

Resistance of all three coils in series 2.237ω @ 26.5°C. T.R. 27.5°C. 1000/100 added 0.585 f to ratio coil with secohmmeter in order to obtain balance.

$$0.585 \times 10^{-6} \times 1.0 \times 10^{3} \times 2.237 \times 10^{3} = 1.308\,\omega$$
$$= 13{,}080 \text{ kilometers.}$$

t	$(1\cdot0077)^t$	0·05405(1·0077)^t	$(1\cdot0077^t - 1)$	Radiation from sq. cm.	Total radiation Watts	Total correct Watts	t log 1·0077
							~~0·02414537~~
6·44	$(1\cdot0077)^{\frac{1}{2}}$	0·06726	0·0506	0·034·03 $\times 10^{-4}$	0·01739	—	0·02414537
8·76	1·1957		0·0695	0·046775	0·02389	0·013349	0·0291822
11·34			0·09009	0·061114	0·03125	0·02015	0·0377769
15·46			0·1259	0·084688	0·04328	0·02002	0·0515819
18·8			0·1553	0·104445	0·05337	0·0281	0·0626236
30·14			0·2601	0·174894	0·08938	1·01421	0·1090054
52·04			0·4906	0·32998	0·1686	0·0760	0·1735565
62·96			0·6196	0·416774	0·2130	0·0852	0·2094055
83·22			0·89934	0·60090	0·3071	0·10974	0·2772308
102·6			1·1968	0·80497	0·4113	0·1113	0·3147914

(8)

Carrying Capacity of Conductors.

July 26th 1899 Tuesday.

Five strips of bright brush copper were suspended across the galvanometer room about 250 cms from the floor and about 24 cms apart. These strips were prepared as follows:-

No. of strip	Length cms	Breadth	Thickness	Surface per sq. cm	Area sq. cms	Equivalent diameter of equal area cms	Equivalent diameter of equal C. section	Nature of applied to wire
I	591	2·514	~~0·0775~~ 0·0165	5·11	~~0·00595~~ 0·014194	0·239	1·63	Superficial coating. Bright copper, untouched.
II	594·5	1·1"	~~0·0750~~ 0·0065"	2·01 sq. in	~~0·0375~~ 0·0065"	0·0946" 0·091"	0·61"	Varnish with lampblack + shellac and black adhesive varnish
III	591							Brown shellac varnish. Fairly thick coating.
IV	588·3				Equivalent C.M. 9250			B.W.S. thin layer produced by painting with No. 8 adhesive varnish
V	586							Lampblacked by smoking under flame

A photograph was taken by Mr Dixon of the entire arrangement. The temp. of the air was taken by means of a thermometer suspended beneath the strips. Both in this and the preceding experiment the air was kept as still as possible in the room by keeping the doors and windows closed.

The gas flow used in multiple gives 0·01210. The elec. res. of the galv. was 2730 ohms.

1899

No. of Obs.	Time	Long Resp. amplitude	Amplitude	Potentiometer amplitude	Amplitude	Mean Potentiometer Res.	Mean amplitude	Mean res. of wire @ 23·3°C.	Mean res. of wire @ 0°C.	Resistivity and % cons.
1	4.23	–		0·0180	2·975					
2	4.8	–		0·0460	7·602	0·04149	7·304	~~0·02085~~	~~0·02036~~	~~1·663~~
3	15.20/30	0·75 a 1	12·7	0·0769	12·71	0·0751	12·41	0·02293 ω	0·02347 ω	1666
4	15.36/50	1·05	17.	0·1096	18·11	0·10144	17·26			97·2%
5	16.55/17·10	2·90	24	0·1545	25·53	0·1551	25·63			
6	17.53/18·10	3·50	27	0·1750	28·92	0·1738	29·73			
7	18.15/30	4·2	31	0·2025	33·47	0·2024	33·46			
8	26/38	4·85	34·5	0·2208	36·50	0·2230	36·86			
9	34/45	5·7	39·5	0·2500	41·32	0·2517	41·61			
10	40/55	6·9	48·5	0·3114	51·47	0·3134	51·80			
11	46/19.04	8·8	61·5	0·4180	69·08	0·4118	68·06			
12	52/24	9·4	70·5	0·4479	74·02	0·4469	73·86			
13	35/35	10·5	82	0·5150	85·12	0·5126	84·72			
14	45/50	11·25	90	0·5600	92·56	0·5596	92·32			
15	49/20.05	–								
16										

No. of Obs.	Time	Res. added to wire	Total res. in wire at 27°	Res. of wire	$\frac{R}{T}$	Rise of temp. above C.	Current amperes C.	Current amperes C°.	Res. per cm.	Energy per sq. cm. Watts.	Emissivity
1	15.20	3120	5850	0·02593							
2	15.20/30	3180	5910	0·02662	1·010	2·58	12·65	13·8	4·4232 $\times 10^{-5}$	(3818 $\times 10^{-4}$) 3·1770	1·23 $\times 10^{-12}$
3	15.36/50	3265	5995	0·02687	1·0250	6·44	17·3	29·3	4·4495	(3865 $\times 10^{-4}$) 6·71	9·74 $\times 10^{-12}$
4	16.55/17·10	3320	6050	0·02862	1·0344	8·76	20·7	32·7	4·5387	(3788 $\times 10^{-4}$) 1·7620	1·99 $\times 10^{-12}$
5	17.53/18·10	3380	6110	0·02708	1·0144	11·34	23·5	37·2	4·5822	5·1420 $\times 10^{-4}$ 2·35	2·11
6	18.15/30	3470	6200	0·02748	1·060	15·46	26·9	42·6	4·6350	6·33 $\times 10^{-4}$ 2·969	1·91
7	26/38	3545	6275	0·02792	1·073	18·91	29·6	47·31	4·706	8·15 $\times 10^{-4}$ 3·77	2·02
8	34/45	3805	6535	0·02897	1·117	30·14	32·9	52·63	4·901	1·3595 $\times 10^{-3}$ 6·26	2·03
9	40/55	4300	7030	0·03116	1·202	52·04	38·1	60·89	5·273	2·1465 $\times 10^{-3}$ 1·1600	2·19
10	46/19.04	4550	7280	0·03227	1·244	62·96	39·9	64·61	5·4600	2·9215 $\times 10^{-3}$ 1·389	2·21
11	52/24	5010	7740	0·03431	1·323	83·22	44·7	71·74	5·805	4·1650 $\times 10^{-3}$ 1·941	2·33
12	35/35	5450	8180	0·03626	1·399	102·6	48·5	82·19	6·134	5·2262 $\times 10^{-3}$ 2·435	2·37
13		2970	5700	~~0·02525~~							

Temp elevation °C	Rate per min Albumen corrected	Energy per cm²	Total Radiation	Radiation per sq cm	Radiation of triple wire	Ratio	Wt	Total energy
3.1	0.003	0.0132	0.0102	0.0020	0.0021			
4.6	0.0075	0.0347	0.0297	0.00581	0.0023	2.52	1	2.52
6.4	0.011	0.0502	0.0392	0.00767	0.0275	2.79	1	2.79
8.8	0.015	0.0615	0.0455	0.00890	0.0252	1.71	1	1.71
10.5	0.018	0.0748	0.0608	0.0119	0.0062	1.83	2	3.66
17.8	0.029	0.125	0.096	0.0188	0.010	1.88	2	3.76
24.4	0.046	0.226	0.180	0.0352	0.018	1.96	2	3.92
26.3	0.056	0.272	0.216	0.0423	0.023	1.84	3	5.52
46.1	0.067	0.370	0.303	0.0593	0.029	2.04	3	6.12
54.9	0.076	0.452	0.376	0.0736	0.0363	2.10	3	6.30
							18	36.30
							Mean =	2.02
4.4	0.007	0.0132	0.0062	0.00121	0.0025			
5.4	0.0096	0.0362	0.0266	0.00521	0.003	1.74	1	1.74
6.7	0.012	0.0501	0.0381	0.00746	0.0043	1.74	1	1.74
9.0	0.015	0.0613	0.0463	0.00906	0.0053	1.71	2	3.42
11.6	0.019	0.0787	0.0597	0.01168	0.007	1.67	2	3.34
17.8	0.029	0.1247	0.0957	0.01873	0.0103	1.82	3	5.46
31.2	0.038	0.2262	0.1882	0.0368	0.0195	1.89	3	5.67
37.1	0.056	0.2719	0.2159	0.0423	0.023	1.84	3	5.52
46.6	0.068	0.3686	0.3006	0.0588	0.0295	1.99	3	5.97
56.2	0.078	0.4514	0.3734	0.0731	0.0375	1.95	3	5.85
							21	38.71
							Mean =	1.84
5.7	0.008	0.0361	0.0283	0.00515	0.003			
8.0	0.013	0.0496	0.0366	0.00716	0.0047	1.52	(1)	1.52
10.3	0.017	0.0608	0.0438	0.00857	0.006	1.43	(1)	1.43
13.7	0.022	0.0728	0.0508	0.00994	0.0075	1.33	(1)	1.33
20.6	0.033	0.1244	0.0914	0.0179	0.0125	1.43	(2)	2.86
35.0	0.053	0.2261	0.1731	0.0339	0.022	1.54	(2)	3.08
42.3	0.063	0.2727	0.2097	0.0410	0.027	1.52	(2)	3.04
53.9	0.076	0.3722	0.2962	0.0580	0.0355	1.63	(4)	6.52
65.2	0.086	0.4583	0.3723	0.0729	0.045	1.62	(4)	6.48
							18	27.78
							Mean	1.54
4.1	0.0065	0.0131	0.0066	0.00129	0.0023			
6.2	0.010	0.0363	0.0263	0.00515	0.0037	1.39	(1)	1.39
8.5	0.014	0.0498	0.0358	0.00701	0.0047	1.49	(1)	1.49
11.6	0.019	0.0612	0.0422	0.00826	0.0065	1.27	(1)	1.27
14.7	0.025	0.0786	0.0536	0.0105	0.0085	1.24	(2)	2.48
22.4	0.036	0.1253	0.0893	0.0175	0.0135	1.30	(2)	2.60
37.1	0.056	0.2279	0.1719	0.0336	0.0230	1.46	(3)	4.38
45.4	0.066	0.2759	0.2099	0.0411	0.029	1.42	(4)	5.68
58.5	0.080	0.3784	0.2924	0.0574	0.0395	1.48	(4)	5.92
69.1	0.089	0.46644	0.37574	0.0735	0.0482	1.53	(4)	6.12
							22	31.33
							Mean	1.42

No. of obs.	Rec. added to ship	Total rec'd ship cat.	Rec. of ship	R/r	Rise of temp. above	Current amperes C	C'	Rec. per cm	Energy per cm	Thermo per sq. cm	Emissivity
1	3130	5860	0.02597					4.367 $\times 10^{-4}$			
2	3160	5890	0.02611	1.005	1.24	17.3	299.3	4.391	6.752 $\times 10^{-3}$	3.146 $\times 10^{-4}$	2.146 $\times 10^{-4}$
3	3200	5930	0.02625	1.012	3.09	20.7	823.7	4.420	1.323 $\times 10^{-2}$	6.164	2.00
4	3240	5970	0.02646	1.018	4.64	33.5	1122	4.450	3.666	1.708 $\times 10^{-3}$	1.68
5	3280	6010	0.02664	1.025	6.44	34.9	1362	4.480	5.018	2.338	1.63
6	3330	6060	0.02686	1.034	8.76	41.6	1731	4.517	6.152	2.866	2.27
7	3380	6110	0.02708	1.042	10.82	51.1	2223	4.553	7.892	3.673	3.40
8	3435	6265	0.02777	1.069	17.75	68.1	4638	4.670	1.253 $\times 10^{-1}$	5.836	3.26
9	3800	6630	0.02935	1.114	23.38	73.9	5461	4.870	2.259	1.051 $\times 10^{-2}$	3.58
10	3965	6685	0.02963	1.111	36.33	84.7	7174	4.923	3.721 $\times$	1.268	3.49
11	4180	6910	0.03063	1.179	46.12	92.3	8519	5.151	3.664	1.722	3.73
12	4380	7110	0.03152	1.213	56.88			5.301	4.577	2.105	3.84
13	2000	5720									
14											

Lampblack, Gillette — 23.5°

No. of obs.	Rec. added to ship	Total rec'd ship cat.	Rec. of ship	R/r	Rise of temp. above	Current amperes C	C'	Rec. per cm	Energy per cm	Thermo per sq. cm	Emissivity
1	2070	5800	0.02571					4.350 $\times 10^{-4}$			
2	3105	5835	0.02586	1.006	1.55	12.4	153.8	4.375	6.723 $\times 10^{-3}$	3.135 $\times 10^{-4}$	2.02 $\times 10^{-4}$
3	3170	5900	0.02615	1.017	4.38	17.3	299.3	4.424	1.324 $\times 10^{-2}$	6.168	1.44
4	3240	5970	0.02644	1.021	5.41	20.7	423.7	4.440	3.624	1.689 $\times 10^{-3}$	3.12
5	3220	5950	0.02637	1.026	6.70	33.5	1122	4.462	5.007	2.333	3.48
6	3275	6005	0.02663	1.035	9.02	34.9	1362	4.504	6.134	2.858	3.17
7	3330	6060	0.02686	1.045	11.60	41.6	1731	4.534	7.866	3.665	3.16
8	3470	6200	0.02748	1.069	17.78	51.8	2683	4.649	1.247 $\times 10^{-2}$	5.810	3.27
9	3770	6500	0.02882	1.121	31.18	68.1	4638	4.777	2.262	1.054 $\times 10^{-2}$	3.32
10	3910	6640	0.02943	1.144	37.10	73.9	5461	4.879	2.719	1.267	3.58
11	4125	6855	0.03038	1.181	46.63	84.7	7174	5.049	3.698	1.717	3.68
12	4335	7065	0.03131	1.218	56.18	92.3	8519	5.297	4.5114	2.103	3.74
13	2970	5700									

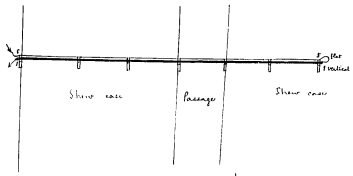
Bronze Gillette — 23.5°

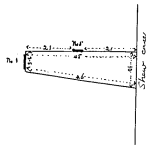
No. of obs.	Rec. added to ship	Total rec'd ship cat.	Rec. of ship	R/r	Rise of temp. above	Current amperes C	C'	Rec. per cm	Energy per cm	Thermo per sq. cm	Emissivity
1	2965	5695	0.02525					4.291 $\times 10^{-4}$			
2	2990	5720	0.02535	1.004	1.03	12.4	153.8	4.307	6.624 $\times 10^{-3}$	3.086 $\times 10^{-4}$	2.00 $\times 10^{-4}$
3	3040	5770	0.02557	1.013	3.35	17.3	299.3	4.347	1.307 $\times 10^{-2}$	6.061	1.81
4	3090	5820	0.02580	1.022	5.67	28.7	823.7	4.384	3.611	1.683 $\times 10^{-3}$	2.97
5	3140	5870	0.02602	1.031	7.99	33.5	1122	4.422	4.961	2.311	2.89
6	3200	5930	0.02628	1.040	10.31	34.9	1362	4.466	6.083	2.834	2.75
7	3270	6000	0.02660	1.053	13.66	41.6	1731	4.521	7.824	3.646	2.67
8	3425	6155	0.02728	1.080	20.62	51.8	2683	4.636	1.2144 $\times 10^{-2}$	5.796	2.81
9	3740	6470	0.02868	1.136	35.04	68.1	4638	4.875	2.261	1.054 $\times 10^{-2}$	3.01
10	3900	6630	0.02939	1.164	42.26	73.9	5461	4.994	2.727	1.271	3.01
11	4155	6885	0.03052	1.209	53.85	84.7	7174	5.187	3.722	1.734	3.22
12	4410	7140	0.03165	1.253	65.18	92.3	8519	5.378	4.583	2.135	3.38
13	2850	5580									

Cu — 23.3°

No. of obs.	Rec. added to ship	Total rec'd ship cat.	Rec. of ship	R/r	Rise of temp. above	Current amperes C	C'	Rec. per cm	Energy per cm	Thermo per sq. cm	Emissivity
1	2950	5680	0.02518					4.296 $\times 10^{-4}$			
2	2985	5715	0.02534	1.006	1.55	12.4	153.8	4.324	6.650 $\times 10^{-3}$	3.098 $\times 10^{-4}$	2.00 $\times 10^{-4}$
3	3045	5775	0.02560	1.016	4.12	17.3	299.3	4.367	1.307 $\times 10^{-2}$	6.089	1.48
4	3090	5820	0.02580	1.024	6.18	28.7	823.7	4.402	3.626	1.689 $\times 10^{-3}$	2.73
5	3140	5870	0.02602	1.033	8.50	33.5	1122	4.440	4.981	2.321	2.73
6	3205	5935	0.02631	1.045	11.60	34.9	1362	4.490	6.115	2.849	2.46
7	3275	6005	0.02662	1.057	14.69	41.6	1731	4.541	7.862	3.663	2.49
8	3445	6175	0.02737	1.087	22.42	51.8	2683	4.670	1.253 $\times 10^{-2}$	5.838	2.61
9	3770	6500	0.02881	1.144	37.10	68.1	4638	4.915	2.279	1.062 $\times 10^{-2}$	2.86
10	3950	6680	0.02961	1.176	45.35	73.9	5461	5.023	2.759	1.286	2.83
11	4245	6975	0.03091	1.227	58.50	84.7	7174	5.214	3.784	1.763	2.81
12	4475	7205	0.03194	1.268	69.06	92.3	8519	5.450	4.644	2.164	3.13
13	2850	5580									

Gentle Graphite — 23.3°





Carrying Capacity of Conductors.

August 1st Thursday.

Finding the emissivity of these strips to be so low, made a special experiment to ascertain the effect of position upon their radiation and convection, for the strips in yesterday's tests were suspended flat but lay over somewhat in the centre of the span and it was thought that if they had been suspended with the plane of the strips vertical the convection might have been greatly facilitated.

Two strips nos (1) + (5) of yesterday, the latter washed and rubbed down with emery paper were fixed upon frames screwed to the show cases. These frames were about one metre apart. On the top rested no. 5 drawn flat. It was about 215 cms above ground and about 25 ft the show cases. At the ends of the frames no 1 was nailed so as to be about 213 cms above ground 21 cms from no 5 and 45 from the show cases, the arrangement being represented by the sketch on the opposite page. A photograph was also obtained.

Grid in multiple arc = 0·0121 ω. Res. of galv 2710 ω per coil. After taking the first set with about 5 and 100 amperes, the strips were exchanged, no 5 being made vertical and no 1 horizontal, no other alteration being made. The test was then repeated. Length of no 1 reduced 7·5

No of Obs.	Time	L.R. Amm. Rdg	Amperes	Potentio Rdg.	Amperes	Mean Potentio Rdg	Mean amperes	Res. of strip per cm @ 26°	Res. of strip @ 0°C per cm	Resistivity compared to Cu	Temp. air
1	11h 11m 50s	0	8	0·0310	5·125	0·0310	5·125				
2	·52 15·00	11·2	89	0·6109	101·0	0·6126	101·3	$4·296 \times 10^{-5}$	$3·902 \times 10^{-5}$	1636 99%	26C

No of Obs. No 1	Res. in cct with strip	Total res. of strip cct	Res. of strip	$\frac{R}{r}$	Rise of temp. above air	Current amperes C. C²	Rise per cm	Energy per cm.	Therms per sq. cm.	Emissivity.
1	2940	5650	0·02523				$4·324 \times 10^{-5}$			
2	5190 (mean of 5 reading)	7400 (mean of 5 reading)	0·03327	1·398	102·6°	101·0 10201	$6·044 \times 10^{-5}$	0·6165	$2·873 \times 10^{-5}$	$2·80 \times 10^{-5}$

No of Obs. No 5	Res. in cct with strip	Total res of strip cct	Res. of strip	$\frac{R}{r}$	Rise of temp. above air	Current C C²	Rise per cm	Energy per cm.	Therms per sq. cm.	Emissivity.
1	2890	5600	0·02501				$4·247 \times 10^{-5}$			
2	5895 (mean of 5 reading)	8205 (mean of 5 reading)	0·03664	1·465	119·8°	101·0 10201	$6·251 \times 10^{-5}$	$6·376 \times 10^{-5}$	$2·971 \times 10^{-5}$	$2·48 \times 10^{-5}$

No of Strip	Position	Length	Breadth	Thickness	Area	Amperes per cm		Emissivity of Platinum strip @ 100°C	Emissivity of upright strip @ 100C	% of vacuum of emissivity
1	Vertical	5993·5	2·54	0·0165	0·04194	5·81		$2·4 \times 10^{-5}$	$2·8 \times 10^{-5}$	17%
5	Horizontal	5986	2·54	0·0165	0·04194	5·11				

To confirm these results repeated them as follows:- with strips exchanged. All the readings were repeated several times to obtain a fair mean value.

Temp	1.0077^t	0.06625(1.077)	$t \lg 1.0077$	$(1.0077^t - 1)$	Radiation per sq. cm	Total Radiation	Total Radiation + Convection	Total convection
120.2		0.68666	0.4010885	1.5182	0.1042	0.5323	0.6337	0.1014
85.8		1.428	0.2858285	0.9312	0.0639 11	0.3268	0.3808	0.0540
46.4			0.1545723	0.4275	0.02935	0.1500	0.1898	0.0398
18.9			0.0626284	0.1551	0.010649	0.0544	0.0632	0.0088
1.55			0.0051635 2	0.0126	0.0008824			
101.3			0.3374667	1.1750	0.08068	0.4123	0.5955	0.1832
71.9			0.2395205	0.7360	0.05053	0.2582	0.3605	0.1023
40.2			0.1393183	0.3612	0.02480	0.1267	0.1836	0.0569
16.75			0.0557937	0.1371	0.009413	0.0481	0.0619	0.0138
1.42			0.0047304	0.0110	0.000755			

Carrying Capacity of Conductors contd.

No. of Obs.	Time	L.R. Amm. reading	Amperes	Potentio Meter Rdg.	Amperes	Potentio Meter Rdg.	Mean amperes	Probable error of reading for low	Probable error of reading for high	
1	15.23	-	5	0.0312	5.156	0.0312	5.156			
2	.25/32	11.0	87.5	0.6058	100.1	0.6058	100.1	± 30.2	±23.4	
3	.33/40	9.65	74	0.4941	81.65	0.4916	81.25	± 2.5	0	
4	.40/45	7.70	55	0.3700	61.15	0.3693	61.04			
5	.45/49	4.7	33	0.2228	36.82	0.2230	36.86			
6	.53/56	—	—	0.0570	9.42	0.0571	9.437			
						Runner	100 amps	± 21.3	± 7.7	

No. of Obs.	Res. in strip ext. plate	Total res. in strip ext.	Res. of strip	$\frac{R}{r}$	Rise of temp. above air	Current C	C^2	Res. per cm.	Energy per cm.	Therms per sq. cm.	Emissivity per sq. cm.	Temp air
1	2940	5850	0.02523									
2	5580	8280	0.03590	1.467	129.4	100.1	10,020	6.324×10^{-5}	6.337×10^{-1}	2.953×10^{-4}	2.476×10^{-4}	
3	4820	7520	0.03362	1.333	85.8	81.3	6610	5762	3.808	1.775	2.07	
4	3955	6665	0.02976	1.180	46.4	61.0	3721	5100	1.898	8.845×10^{-3}	1.91	
5	3355	6065	0.02708	1.073	18.8	36.9	1362	4.6461	6.322×10^{-2}	2.947×10^{-2}	1.57	
6	2975	5685	0.02538	1.006	1.55	9.44	89.1	4.3149	3.875×10^{-3}	1.806×10^{-3}	1.17	

No. of Obs.	Res. in strip ext.	Total res. in strip ext.	Res. of strip	$\frac{R}{r}$	Rise of temp. above air	Current C	C^2	Res. per cm.	Energy per cm.	Therms per sq. cm.	Emissivity
1	2890	5600	0.02500								
2	5090	7800	0.03483	1.393	101.3	100.1	10,020	5.943×10^{-5}	5.955×10^{-1}	2.775×10^{-4}	2.74×10^{-4}
3	4450	7160	0.03197	1.279	71.9	81.3	6610	5.455	3.605	1.680	2.34
4	3765	6475	0.02891	1.156	40.2	61.0	3721	4.933	1.836	8.556×10^{-3}	2.13
5	3255	5965	0.02663	1.065	16.75	36.9	1362	4.5144	6.190×10^{-2}	2.885×10^{-2}	1.72
6	2920	5630	0.02514	1.0055	1.42	9.42	89.1	4.290	3.823×10^{-3}	1.782×10^{-3}	1.26

No. of strip	Condition	Rise Temp. @ 100 amperes	Emissivity	Condition	Rise of Temp. @ 100 amperes	Emissivity		Radiation on assumption of a convection loss of flat
1	Upright	102°	2.75×10^{-4}	Flat	129.4	2.48×10^{-4}		2.21×10^{-4}
5	Upright	101.3°	2.74×10^{-4}	Flat	119.8	2.45		2.16×10^{-4}

Taking the emission and temp. of the brightened wire calculated on page 6 and on the hypothesis that at any given temp. the radiation varies with the temperature, while the convection is not a function of a freely exposed surface we have

bright strip 93.7°C $\quad 5.11\,r + c = 0.1212$ therms per cm per sec

bright wire 94.7°C $\quad 0.463\,r + c = 0.03343$ - - - - -

whence $r_{94.7} = 0.01889$ and $c = 0.02447$

- $r_{93} = 0.00021 6$

where r is the radiation loss per sqc cm; per °C per sec $= 2.16 \times 10^{-4}$ therms @ 94°C

" c - - convection - per cm; length of conductor per sec $= 2.47 \times 10^{-2}$ @ 94° C.

Tests of a certain Insulating Material.

August 1st Thursday. Received from Mr Ensell a pair of moulded lamp sockets of a red insulator resembling rubber in appearance and named Boneilate. Immersed one of these in dilute H_2SO_4 for an hour and no bad effects were observable on the material but the solution was slightly colored. Then left this socket on the cylinder of the mil. engine on a sheet of paper, exposed to a temperature of about 115 °C for 6 hours. At the end of that time the material had somewhat warped cracked and darkened in color. Socket no 2 weighed in air 13.862, water 2.685 @26°C

from which the sp. g. is 1.36.

After soaking for 20 hours in water and then superficially dried = 14.10 or an increase of only 0.24 gms or 1.6 %. The dried specimen was tested for inflammability by breaking off a piece and holding the same in a Bunsen flame. The piece caught fire after a considerably amount of heating, and burned apart after removal from the flame for some time, slowly extinguishing. It is not fire proof therefore but does not nurture a flame. The soaked piece was then tested mechanically. It cut well takes a thread well, and turns well in a lathe, blunting the tool edge. It is however rather brittle and not so tough as hard rubber. In other respects it much resembles vulcanite fibre. Vulcanized fibre is less inflammable than this material, but hard rubber is much more so.

A specimen of hard rubber weighed in air 16.9820
water @26° 2.6269

A specimen of vulcanized fiber weight sp. gr. 1.183
in air 14.6461
water @26° 0.9670
sp. 1.256

Carrying Capacity of Conductors.

August 2nd Friday

With the view of determining more closely the coefficients of convection and radiation took a series on three bare bright copper wires (two of which had been used before in the out of door test) and suspended across the room on the place of the strips whose heat is given on page 7. The height of the wires was about 250 cms and their distance apart about 50. The two larger wires tested in circuit with the long range ammeter and the smaller separately in circuit with the Ohmch.

Res. of galv. coils 27200 each giz multiple in first test, series in second

No. of wire	Length	Diam.	Surface per cm.	Area	C.M.	Condition of surface	Res. per cm. @ 0°C	Resistivity @ 0°C	Conductivity %	Resistivity	Temp air
1	58.4	{0.1345 / 0.3416}	1.073	9.0916	18,200	bright	1.95×10^{-5}	1.765×10^{-5}	100%	1617	27°C
2	58.15	{0.1119 / 0.279}	0.8765	0.0611	12,100	"	2.924×10^{-5}	2.702×10^{-5}	98.1	1651	
3	58.23	{0.0356 / 0.0904}	0.2840	0.00648	1270	"	2.921×10^{-4}	2.644×10^{-4}	95.5	1697	

t° ↑ 15.2°	Coefficient of radiation	Total rad. per cm²	Energy per cm²	Convection per cm²
4.5	0.00214	0.00258	0.01504	0.00746
11.1	0.006	0.006644	0.02710	0.02066
24.2	0.0124	0.0133	0.05636	0.04306
42.8	0.0250	0.0268	0.09577	0.07699
66.5	0.0465	0.0524	0.1757	0.1233
82.2	0.0615	0.0660	0.2293	0.1623
100.2	0.0800	0.0858	0.2768	0.1910
7.3	0.004	0.00351	0.0155	0.0120
20.6	0.012	0.0105	0.0429	0.0324
44.1	0.0285	0.0250	0.09142	0.0649
68.9	0.0575	0.0504	0.1688	0.1184
125.0	0.111	0.0973	0.3171	0.2200
4.4	0.0024	0.0007	0.00516	0.00446
17.5	0.0105	0.00298	0.03110	0.0281
46.4	0.030	0.00852	0.07548	0.06696
110.8	0.093	0.0264	0.1637	0.1373

Carrying Capacity of Conductors

(13)

Mark No.	Time	E.M.F. Am	Amperes	Res. in Ω (0.0139)	Amperes	Mean Potential Drop	Mean amperes
1	14.30	—	—	0.0324	5.355	0.0325	5.371
2	38	2.1	23	0.1360	22.48	0.1363	22.53
3	45	4.75	34	0.2200	36.36	0.2206	36.46
4	55	6.9	48	0.3124	51.63	0.3108	51.37
5	15.5	8.7	63	0.3925	64.87	0.3987	65.90
6	15	10.4	80	0.5140	84.95	0.5118	84.59
7	16.5	11.2	90	0.5820	93.58	0.5698	94.18
8	18	11.9	99	0.6162	101.9	0.6117	101.1
9		Obnl.					
10	10.50	0.225	2.18	0.0500	2.004	0.0500	2.004
11	45	1.030	5.28	0.1304	5.226	0.1308	5.242
12	11.00	2.190	9.29	0.2370	9.498	0.2371	9.503
13	15	2.790	14.31	0.3690	14.790	0.3691	14.79
14	45	3.760	19.28	0.4978	19.950	0.4983	19.97

#1 No. Mes.	Res. in Ω of wire (0.0139)	Total res. in Ω of wire (0.0139)	Res. of wire	R/r	Rise of temp. in wire	Current C	C²	Res. per cm.	Watts per cm.	Watts per sq. cm. surface	Therms per sq. cm.	Conducivity
1	170	2890	0.0139					1.95×10^{-5}				
2	120	2840	0.01159	1.0175	4.51	22.53	506.3	1.984	1004×10^{-5}	2.22°	2.228×10^{-5}	5.056×10^{-5}
3	50	2770	0.01188	1.043	11.08	36.5	1332	2.035	2.710		6.014	5.428×10^{-5}
4	80	2800	0.01246	1.094	24.22	51.4	2642	2.133	5.636		1.251×10^{-4}	5.164×10^{-5}
5	265	2985	0.01328	1.166	42.77	65.9	4343	2.274	9.877		2.192	5.125×10^{-5}
6	500	3220	0.01433	1.258	66.48	84.6	7157	2.4574	1.757×10^{-1}		3.899	5.614×10^{-5}
7	655	3375	0.01502	1.319	82.20	94.2	8874	2.5722	2.283		5.068	6.165×10^{-5}
8	835	3555	0.01582	1.389	100.2	101.1	10220	2.709	2.768		6.143	6.132×10^{-5}

#2 No. Mes.	Res. in Ω (0.0139) cat with wire	Total res. in Ω wire cat.	Res. of wire	R/r	Rise of temp. in	Current C	C²	Res. per cm.	Watts per cm.	Watts per sq. cm. surface	Therms per sq. cm.	Conducivity
1	1180	3900	0.01735					2.924×10^{-5}				
2	1290	4010	0.01784	1.0282	7.27	28.54	506.3	3.068	1.553×10^{-1}		4.218×10^{-5}	5.903×10^{-5}
3	1490	4210	0.01873	1.080	20.62	36.5	1332.	3.221	4.290		1.165×10^{-4}	5.65×10^{-5}
4	1845	4565	0.02031	1.171	44.06	51.4	2642	3.565	9.416		2.558	5.804×10^{-5}
5	2360	5080	0.02260	1.303	78.08	65.9	4343	3.887	1.688×10^{-1}		4.584	5.871×10^{-5}
6	3070	5790	0.02576	1.485	125.0	84.6	7157	4.430	3.171		8.612	6.891×10^{-5}
7	3640	6360	0.02830	1.631	162.6	94.2	8874	4.867	4.319		1.173×10^{-1}	7.214×10^{-5}
8	4160	6880	0.03061	1.765	197.2	101.1	10220	5.264	5.379		1.461	7.406×10^{-5}

#3 No. Mes.	Res. in Ω (0.0139) cat with wire	Total res. in Ω wire cat.	Res. of wire	R/r	Rise of temp. above air	Current C	C²	Res. per cm.	Watts per cm.	Watts per sq. cm. surface	Therms per sq. cm. surface	Conducivity
1	6550	9270	0.07010					2.921×10^{-4}				
2	6710	9430	0.1750	1.017	4.39	5.24	27.46	2.970	8.156×10^{-3}		6.936×10^{-3}	1.561×10^{-3}
3	7175	9895	0.1816	1.068	17.52	9.50	90.25	3.118	3.110×10^{-2}		2.607×10^{-2}	1.494×10^{-3}
4	8220	10940	0.2007	1.180	46.39	14.79	219.0	3.446	7.568		6.327	1.364×10^{-3}
5	10535	13255	0.2432	1.430	110.8	19.77	391.0	4.176	1.637×10^{-1}		1.372×10^{-1}	1.238×10^{-3}

10°

5·11 r + c = 0·043
0·2841 r + c = 0·020
4·826 r = 0·023
r = 0·004765
c = 0·01865

20°

5·11 r + c = 0·037
0·2841 r + c = 0·036
4·826 r = 0·051
r = 0·01057
c = 0·0338

30°

5·11 r + c = 0·135
0·2841 r + c = 0·052
4·826 r = 0·083
r = 0·01720
c = 0·04471

40°

5·11 r + c = 0·1641
0·2841 r + c = 0·065
4·826 r = 0·119
r = 0·02466
c = 0·0580

50°

5·11 r + c = 0·235
0·2841 r + c = 0·080
4·826 r = 0·155
r = 0·03212
c = 0·0709

60°

5·11 r + c = 0·293
0·2841 r + c = 0·094
4·826 r = 0·198
r = 0·04103
c = 0·0824

70°

5·11 r + c = 0·350
0·2841 r + c = 0·109
4·826 r = 0·241
r = 0·04995
c = 0·0958

80°

5·11 r + c = 0·407
0·2841 r + c = 0·121
4·826 r = 0·286
r = 0·05927
c = 0·1042

90°

5·11 r + c = 0·4612
0·2841 r + c = 0·136
4·826 r = 0·328
r = 0·06796
c = 0·1167

100°

5·11 r + c = 0·525
0·2841 r + c = 0·149
4·826 r = 0·376
r = 0·0779
c = 0·1289

10°

1·0737 r + c = 0·026
0·2841 r + c = 0·020
0·789 r = 0·026
r = 0·0336
c = 0·0336

20°

1·0737 r + c = 0·051
0·2841 r + c = 0·036
0·789 r = 0·015
r = 0·0190
c = 0·0306

30°

1·0737 r + c = 0·079
0·2841 r + c = 0·052
0·789 r = 0·027
r = 0·0342
c = 0·0423

40°

1·0737 r + c = 0·106
0·2841 r + c = 0·065
0·789 r = 0·041
r = 0·05196
c = 0·050

50°

5·11 r + c = 0·184
1·0737 r + c = 0·106
4·037 r = 0·078
r = 0·07932
c = 0·0853

Carrying Capacity of Conductors.

From the observed dissipation of heat by the bright, bare suspended copper wire and strip we obtain the following analysis of the convective and radiative emissivity at different temperature elevations.

Elev. temp. °C	Wire selected	Total convection watts	Total convection therms.	Radiation per sq. cm. Watts	Radiation per sq. cm. therms.	Radiation per sq. cm. Watts	Radiation per sq. cm. therms.	Adjusted Radiations 40° C.	Adjusted Radiations 40° C.	Adjusted Radiation per sq. Watts		To follow 30° table not Watts
10°		0·01865	0·004444	0·004765	0·001134	0·000477	0·000113	0·000113	0·000047	+ 0·000066	0·005337
20°		0·0338	0·00786	0·01057	0·002516	0·000529	0·000126	0·000126	0·000529	+ 0·000063	0·01120
30°	Bright strip	0·04471	0·01121	0·01720	0·004095	0·000573	0·000136	0·000137	0·000575	+ 0·00018	0·01738
40°	1 doubled wire diam.	0·0580	0·01381	0·02466	0·005871	0·000617	0·000147	0·000147	0·000617	−0·000040	0·02426
50°		0·0709	0·01688	0·03212	0·007648	0·000642	0·000153	0·000155	0·000650	−0·000082	0·03160
60°	0·0906	0·0824	0·01962	0·04103	0·009768	0·000684	0·000163	0·000163	0·000684	−0·00154	0·03949
70°		0·0958	0·02287	0·04995	0·011890	0·000714	0·000170	0·000170	0·000714	−0·00193	0·04862
80°		0·1042	0·02481	0·05927	0·01411	0·000741	0·000176	0·000176	0·000741	−0·00204	0·05723
90°		0·1167	0·02778	0·06796	0·01618	0·000755	0·000180	0·000181	0·000760	−0·00078	0·06718
100°		0·1289	0·03022	0·07790	0·01855	0·000779	0·000185	0·000185	0·000779		0·07790

An examination of the results obtained by Mm. Dulong + Petit express the law of emissivity by the equation:

$$e = m\,t^{(1.233)} + n\{(1.0077)^t - 1\}$$

where t is the temp: elevation in °C and m + n are constants

	ratio 1.20°	ratio 1.20°
$1.0077^{10} - 1 = 0.0793$		
$1.0077^{20} - 1 = 0.1658$		1·0
$1.0077^{30} - 1 = 0.2592$	1·0	1·551
$1.0077^{40} - 1 = 0.3591$	1·396	2·166
$1.0077^{50} - 1 = 0.4678$	1·819	2·822
$1.0077^{60} - 1 = 0.5845$	2·273	3·526
$1.0077^{70} - 1 = 0.7108$	2·764	4·287
$1.0077^{80} - 1 = 0.8471$	3·294	5·109
$1.0077^{90} - 1 = 0.9944$	3·866	5·991
$1.0077^{100} - 1 = 1.1534$	4·485	6·957

Elev. temp. °C	Calculated rate per sq. cm. Watts as above		Calc: rate from 30° in last table by Dulong + Petit law	Calc: rate from 30° in this by power law	Difference		
10°	0·004765	1	0·005301	0·005365	+ 0·000068		
20°	0·01057	2·2	0·01109	0·01188	+ 0·000081		
30°	0·01720		0·01720 ←	0·01766	+ 0·000046		
40°	0·02466	1·5	0·02401	0·02466 ←			
50°	0·03212	1·4	0·03128	0·03212	0		
60°	0·04103	1·28	0·03908	0·04013	− 0·000090		
70°	0·04995	1·22	0·04753	0·04881	− 0·000114		
80°	0·05927	1·22	0·05665	0·05816	− 0·000111		
90°	0·06796	1·18	0·06648	0·06826	+ 0·000030		
100°	0·07790	1·16	0·07714	0·07919	+ 0·00129		

This very remarkable agreement proves the application of Dulong + Petit's law.

do that @ 30° $n\{1.0077^{30} - 1\} = 0.02466$ Watts $\therefore n = 0.02466/0.2592 = 0.06866$ Watts

@ 100° $m\{1.0077^{100} - 1\} = 0.07919$. $\therefore n = 0.07919/1.1534 = 0.06866$

Also $m \times 1.0077^{33} = 0.06866$ Watts.

$\therefore m = 0.06866/1.2207 = 0.05625$

+ the complete expression for the radiation of a bright wire t° above the surrounding air at θ°C is

$$r = 0.05625\,(1.0077)^{\theta}\{1.0077^{t} - 1\}$$ Watts per sq. cm

Carrying Capacity of Phonograph Double cord.

In the present form of strand phonograph conductor there are 79 wires each 0.0088" diam: = 77.5 c.m. each × 79 = 6125 c.m. in all. That is practically equivalent to a number 14 B.W.G.

The accepted limit of the length of this strand that can be used with the phonograph is 12 feet doubled = 24 feet.

= 24 × 0.0015 = 0.0360 ω

20 feet distance	=	40 feet of wire	=	0.0009 ω per ft	=	0.109"	# 12 B.W.G.	# 9 B.W.G.
30 - -	=	60 - - - -	=	0.00006 ω - - -	=	0.1324"	# 10 B.W.G.	# 8
40 - -	=	80 - - - -	=	0.00045 ω - - -	=	0.1148"	# 9 B.W.G.	# 7
50 - -	=	100 - - - -	=	0.00036 ω - - -	=	0.165"	# 8 B.W.G.	# 6
75 - -	=	150 - - - -	=	0.00024 ω - - -	=	0.203"	# 6 B.W.G.	# 4
100 - -	=	200 - - - -	=	0.00018 ω - - -	=	0.258"	# 4 B.W.G.	# 3
150 - -	=	300 - - - -	=	0.00012 ω - - -	=	0.286"	# 2 B.W.G.	# 1
200 - -	=	400 - - - -	=	0.00009 ω - - -	=	0.320"	# 0 B.W.G.	# 0

August 6th Tuesday.

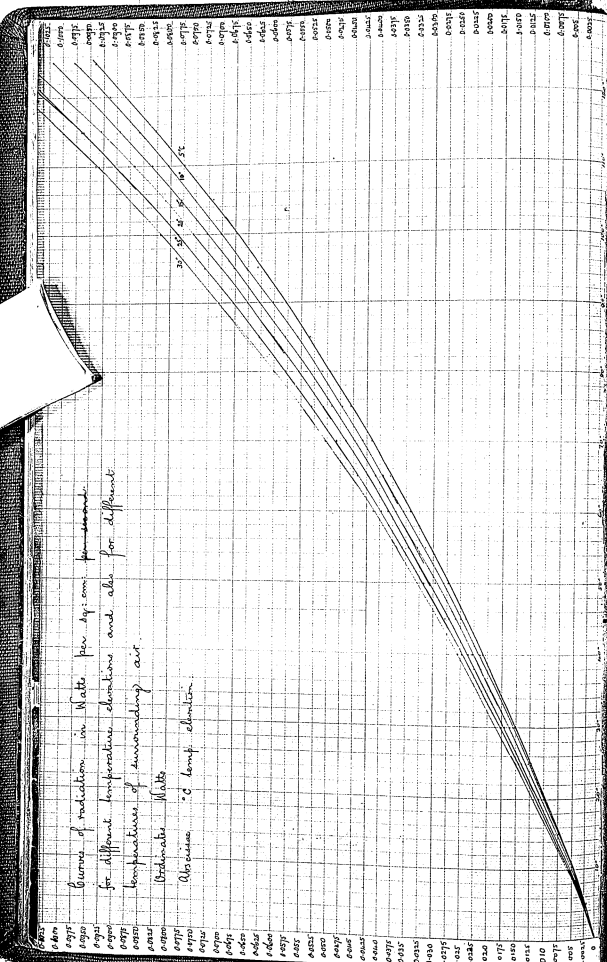
Found by experiment at the Phonograph Works with Frank Osborne that a 4 cell potash battery that has been ~~a~~ working for forty hours, operated a phonograph (fair sample) satisfactorily through 25 feet of bare soft copper wire 0.058" (0.14173 cm) diameter. The res: per cm: of this wire (vide p. 6) is 1.056×10^{-6} ω per cm. = 32.6×10^{-6} ω per foot = 815×10^{-4} or 0.0815 ω for 25 feet. Let us say 22.0 feet of this wire to give a good margin. On this basis 0.0650 ω

Distance	Length wire	Res: per foot	Total res	Diam: wire	Nearest B.W.G. gauge	Nearest B.&S. gauge	
10 20 feet	40 20 feet	0.00162	0.0650 ω	0.058"	# 15	# 12	
30 -	60	0.00108	~~0.0650~~	0.096"	# 13	# 10	
40 -	80	0.00081		0.111	# 12	# 9	
50 -	100	0.00065		0.127	# 10	# 8	
75 -	150	0.000433		0.153	# 8	# 6	
100 -	200	0.000325		0.180	# 7	# 5	
150 -	300	0.000217		0.220	# 5	# 3	
200 -	400	0.000163		0.250	# 3	# 2	

Test of an overmilling horse shoe flat magnet on 5th August for Mr Dixon. 13.4 ω on each link variable as though some bad contact in each, and 6.7 ω in multiple arc. # 14 B.W.G. wire.

Meteorological Record.

Date	Time	Barometer Inches	Barometer Cms	Rdg. Temp. of Barom. in Mm	Rdg. Temp. of Barom. in °C	Thermom. rdgs Max	Thermom. rdgs Min	Thermom. rdgs Dry	Thermom. rdgs Wet	Rainfall last 24 hrs	Clouds	Wind	Weather remarks
August	Noon	29.862	75.87	75°	29.733	84°	60°	79°	76°	1.31"	-	NE	Raining
1.													
2.		29.931	76.05	77°	29.801	88°	58°	81°	77°	—	-	W	Fair
3		30.024	76.26	75	29.895	82°	61°	80°	75°	0.62"	-	SW	Raining & hailstorm
4		30.034	76.30	75	29.909	87°	65°	77°	72°	—	-	WSW	Fine
5		29.994	76.17	74°	29.868	86°	63°	78°	76°	0.14"	-	S	Overcast
" 6	"	30.088	76.48	72°	29.964	80°	60°	71°	67	—	-	E	Fine
7		30.024	76.26	74°	29.898	81°	61°	78°	74°	—	-	SE.	Fair
8		30.066	76.36	73°	29.963	82°	60°	81°	75°	0.40"	-	W	Fine
9		29.944	76.14	72°	29.864	84°	60°	74°	71°	—	-	W	Fair, overcast.
10		29.756	75.73	75°	29.624	78°	69°	77°	74°	0.20"	-	SW	Rain, overcast
11		29.824	75.75	77°	29.698	82°	62°	80°	76°	—	-	W	Fine
12		30.020	76.24	70°	29.906	80	62°	70	65	—	-	W	Fine.
" 13	"	30.062	76.34	72°	29.942	79°	55°	78°	74°	—	-	NW	Fair
14		29.704	75.46	74°	29.578	78°	52°	79°	75	1.80"	-	SW	Fair
15		29.726	75.54	76°	29.610	82°	55°	79°	75°	0.06"	-	SW	Overcast
16		30.042	76.31	76°	29.910	78°	56°	78°	74°	—	-	SW	Fair
17		30.120	76.50	74°	29.994	81°	62°	79°	72°	—	-	W	Fine
18		29.990	76.15	77°	29.855	83°	61°	81°	78°	—	-	NW	Fine.
19		29.996	76.18	78°	29.838	82°	60°	78°	76°	—	-	SW	Fair
" 20	"	29.834	75.88	76°	29.702	82°	54°	81°	76°	—	-	SW	Fine
21		29.990	76.15	74°	29.864	87°	59°	83°	76°	—	-	E	Fair
22		29.946	76.04	76°	29.814	86°	72°	82°	76°	—	-	NE	Overcast.
23		29.940	75.98	75°	29.781	84°	68°	79°	76°	—	-	W	Overcast.
24		30.014	76.24	75°	29.895	82°	70°	80°	76°	0.30"	-	NW	Fair, overcast.
25		30.132	76.54	75°	30.003	81°	64°	78°	70°	—	-	W	Fine
" 26		29.948	76.09	76°	29.812	80°	61°	74°	70°	—	-	W	Fair
27	"	29.848	75.92	76°	29.712	78°	54°	74°	69°	—	-	W	Fair
28		29.104	76.42	75°	29.975	79°	52°	77°	70°	—	-	NE.	Fair
29		30.118	76.50	76°	29.986	84°	50°	78°	71°	—	-	NE	Fair
30		30.030	76.45	77°	29.945	82°	56°	79°	69°	—	-	E	Fine.
31		29.982	76.15	78°	29.844	85°	64°	82°	75°	—	-	NW	Fine
Sept. 1		29.864	75.87	77°	29.729	81°	61°	80°	73°	—	-	W.NW	Fair
2		29.992	76.15	74°	29.866	80°	60°	78°	72°	—	-	N	Fair. Heavy
3		30.122	76.52	77°	29.987	79°	54°	77°	71°	—	-	W	Fair. Heavy
4		30.026	76.27	76°	29.954	83°	59°	80°	74°	—	-	NW	Fair. Heavy
5		30.032	76.28	74°	29.906	83°	56°	75	69°	—	-	S.	Fair. Nights
6		29.914	76.12	78°	29.776	80°	65°	80°	75°	—	-	S	Fair
7		30.020	76.25	74°	29.894	81°	62°	75°	73°	0.41"	-	NW	Overcast
8		29.994	76.19	76°	29.862	78°	59°	78°	72°	—	-	W	Fair
9		30.032	76.29	74°	29.906	79°	56°	75°	70°	—	-	NE	Overcast
10		29.940	75.90	70°	29.726	78°	60°	65°	64°	0.25"	-	NE	Showery
11		29.776	75.64	66°	29.674	75°	62°	63°	63°	0.20"	-	"	"
12		29.962	76.11	69°	29.854	70°	58°	68°	63°	1.42"	-	N	"
13		29.876	75.92	67°	29.771	71°	60°	68°	65°	2.09"	-	N	"
14		29.984	76.16	68°	29.876	72°	59°	69°	69°	0.38"	-	NE	Fair
15		29.992	76.19	72°	29.872	74°	63°	74°	74°	0.06"	-	W	Fair
16		29.924	76.01	74°	29.798	73°	60°	74°	72°	0.72"	-	S	Fair
17		29.850	75.81	75°	29.721	77°	68°	75°	75°	0.06"	-	SW	Raining
18		29.750	75.55	77°	29.645	79°	64°	69°	66°	4.06"	-	W	Overcast.
19		29.582	75.02	68°	29.433	74°	52°	68°	66°	—	-	W	Fair
20		29.862	75.86	66°	29.786	70°	49°	59°	55°	—	-	W	Overcast
21		29.984	76.14	68°	29.891	69°	46°	76°	55°	—	-	W	Fair
22		29.972	76.10	65°	29.871	71°	43°	66°	58°	—	-	W	Fine
23		30.000	76.20	66°	29.898	61°	42°	56°	52°	—	-	W	Fine
24		30.032	76.28	64	29.936	60°	45°	56	60	—	-	W	Overcast.
25		29.920	76.00	68°	29.827	69°	47°	65°	63°	0.38"	-	E	Raining
26		29.750	75.55	70°	29.621	69°	45°	68°	65°	0.81"	-	NE	Overcast
27		29.924	76.00	76°	29.822	72°	45°	64°	49°	0.06"	-	W	Fine
28		30.050	76.32	76°	29.918	76°	43°	77°	66°	—	-	W	Fine
29		29.998	76.19	76°	29.862	79°	46°	78°	67°	—	-	NW	Fair
30		29.836	75.83	75°	29.707	76°	52°	66°	64°	—	-	N	Overcast



Carrying Capacity of Conductors.

For convenience in calculating the radiation from conductors the following table gives the temp: elevation coefficient.

t°C	log 1·0077	t log 1·0077	$1{\cdot}0077^t$	$1{\cdot}0077^t - 1$	θ 5° $0{\cdot}05625(1{\cdot}0077^t - 1)$	θ 10°	θ 15°	θ 20°	θ 25°
					0·00281				
5	0·0033313	0·0166565	1·0391	0·0391	0·002285	0·0207231	0·0531168	0·0655762	0·0611113
10		0·0333130	1·0797	0·0797	0·004658	0·002375	0·002467	0·002564	0·002665
15		0·0499695	1·1219	0·1219	0·007125	0·004840	0·005020	0·005228	0·005431
20		0·0666260	1·1658	0·1658	0·009691	0·007402	0·007692	0·007994	0·008306
25		0·0832825	1·2114	0·2114	0·012364	0·009691	0·0007	0·01046	0·01087	0·01130
30		0·0999390	1·2587	0·2587	0·015112	0·012364	0·01034	0·01087	0·01144
35		0·1165955	1·3080	0·3080	0·018000	0·015112	0·01071	0·01632	0·01697	0·01763
40		0·1332520	1·3591	0·3591	0·02099	0·018000	0·01871	0·07943	0·02020	0·02099
45		0·1499085	1·4123	0·4123	0·024110	0·02181	0·02266	0·02356	0·02447
50		0·1665650	1·4675	0·4675	0·02733	0·025004	0·02602	0·02704	0·02810
55		0·1832215	1·5249	0·5249	0·03068	0·02839	0·02950	0·03067	0·03187
60		0·1998780	1·5844	0·5844	0·03416	0·03188	0·03312	0·03443	0·03578
65		0·2165345	1·6464	0·6464	0·03778	0·03550	0·03688	0·03833	0·03984
70		0·2331910	1·7108	0·7108	0·04155	0·03926	0·04080	0·04240	0·04406
75		0·2498475	1·7777	0·7777	0·04546	0·04317	0·04484	0·04662	0·04845
80		0·2665040	1·8471	0·8471	0·04951	0·04724	0·04904	0·05097	0·05296
85		0·2831605	1·9194	0·9194	0·05374	0·05145	0·05346	0·05556	0·05774
90		0·2998170	1·9944	0·9944	0·05812	0·05584	0·05802	0·06030	0·06266
95		0·3164735	2·0724	1·0724	0·06268	0·06040	0·06275	0·06522	0·06778
100		0·3331300	2·1534	1·1534	0·06742	0·06513	0·06768	0·07032	0·07308
105		0·3497865	2·2376	1·2376	0·07234	0·07006	0·07278	0·07565	0·07859
110		0·3664430	2·3251	1·3251	0·07745	0·07518	0·07810	0·08116	0·08434
115		0·3830995	2·4161	1·4161	0·08277	0·08048	0·08363	0·08690	0·09029
120		0·3997560	2·5105	1·5105	0·08824	0·08600	0·08935	0·09286	0·09650
125		0·4164125	2·6086	1·6086	0·09402	0·09175	0·09532	0·09906	0·10032
						0·0977	0·10150	0·10550	0·10976

If ρ be the sp: resistivity of a conductor at the limiting temp:
d - - its diameter
t - - elevation of temp. in °C
θ - the temp: of surrounding bodies
m - - coefficient of radiation
c - - strength of current in abs: units

Then the heat generated in watts per cm. is

$\frac{4c^2\rho}{\pi d^2} \times 10^{-7}$ and the heat dissipated is per cm in Watts

$kt\theta + m a^\theta (a^t - 1)\pi d\theta$ where

k is the convection coefficient 0·00175
a - - radiation - 1·0077
m - - surface " "

$$\therefore \quad 4c^2\rho \times 10^{-7} = kt d^2 + \pi m a^\theta (a^t - 1) d^2$$

$$c = \frac{\pi}{2}\sqrt{\frac{10^7\{kt d^2 + \pi m a^\theta (a^t - 1) d^2\}}{\rho}}$$

$$= \frac{\pi 10^4}{6{\cdot}2246}\sqrt{\frac{d^2\{kt + \pi m a^\theta (a^t - 1) d\}}{\rho(1 + at)}}$$

$$= 1581\, d \sqrt{\left\{\frac{kt + m\pi a^\theta (a^t - 1) d}{\rho(1 + bt)}\right\}} \quad \text{where } b = 0{\cdot}00388$$

$$= 1581\, d \sqrt{\left\{\frac{0{\cdot}00175 t + d m \pi \times \lambda}{\rho(1 + bt)}\right\}} \quad \text{where } \lambda \text{ is from above table } a^\theta(a^t - 1)$$

$$\text{in amperes} = 15810\, d \sqrt{\left(\frac{0{\cdot}00175 t + d m \pi \lambda}{\rho(1 + bt)}\right)} = 28{\cdot}9\, d \sqrt{\left\{\frac{0{\cdot}00175 R_0 + t}{1 + 0{\cdot}00388 t}\right\}}$$

where $R_0 = \lambda$

d	dt	$7.4\,dt$	$570\,\pi d_R t^{1.61}$	v	c	$1140\,\pi d_R t^{1.61}$	$\sqrt{}$	c
$d=0.1$								
5	0.5	0.3.7 3.7	5.80 9.46	2.62	6.98 8.37	6.29	2.51	15.93 3.96
10	1.0	0.7.4 7.4	18.68	2.42	9.36 10.1	12.67	3.55	9.471 12.0
20	2.0	14.8 14.8	53.95	2.84	12.01 14.3	25.42	4.87	13.41 16.4
40	4.0	29.6 29.6	173.18	3.87	17.9 21.4	74.77	6.91	18.60 22.6
$d=0.3$								
5	0.15	12.1	18.48	4.3	35.6	19.86	4.46	36.9
10	0.30	22.2	35.01	5.92	48.6	37.15	6.1	50.1
20	0.60	44.4	70.24	8.38	67.56	76.08	8.72	70.3
40	1.20	88.8	141.14	11.9	92.96	154.0	12.4	96.87
$d=0.5$								
5	2.5	18.5	25.79	5.08	70.2	28.08	5.30	73.2
10	5.0	37.0	51.68	7.19	98.4	56.36	7.51	102.7
20	10.0	74	103.74	10.2	137.1	113.47	10.65	143.1
40	20.0	148	209.1	14.5	189	230.2	15.2	198
$d=0.7$								
5	3.5	25.9	34.12	5.84	113	40.33	6.35	123
10	7.0	51.8	68.16	8.26	158	74.5	8.63	165
20	14.0	103.6	137.23	11.7	220	160.9	12.55	238
40	28.0	207.2	276.77	16.6	303	326.3	17.5	319
$d=1.0$								
5	5	37	46.59	6.83	189	51.19	7.21	199
10	10	74	93.36	9.66	264	102.7	10.1	276
20	20	148	187.5	13.7	368	198.9	14.1	379
40	40	296	378.2	19.46	507	420.4	20.5	534
$d=1.5$								
5	6.25	46.25	57.0	7.55	261	62.73	7.92	273
10	12.5	92.5	114.2	10.7	366	125.9	11.2	383
20	25	185	229.3	15.15	509	254.2	15.95	536
40	50	370	462.8	21.5	701	515.5	22.7	740

T	$0.003287T$	$1+0.003287T$	$\sqrt{1+0.003287T}$	$\frac{28.9}{\sqrt{1+0.003287T}}$
20°	0.0776	1.0776	1.0373	27.87
30°	0.1164	1.1164	1.0566	27.36
40°	0.1552	1.1552	1.0748	26.88
50°	0.1940	1.1940	1.0927	26.45
60°	0.2328	1.2328	1.110	26.02
70°	0.2716	1.2716	1.1276	25.64
80°	0.3104	1.3104	1.1447	25.25
90°	0.3492	1.3492	1.1615	24.88
100°	0.3880	1.3880	1.1781	24.53
110°	0.4268	1.4268	1.1945	24.19
120°	0.4656	1.4656	1.2106	23.87

t	R_t	$d=0.1$ πd_R	$570\,\pi d_R$	$1140\,\pi d_R$	$\sqrt{570\,\pi d_R t^{1.61}}$	$\frac{28.9}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d\sqrt{570\,\pi d_R t}}{\sqrt{1+0.003287t}}$	$\sqrt{1140\,\pi d_R t}$	$\frac{28.9\,d\sqrt{1140\,\pi d_R t}}{\sqrt{1+0.003287t}}$
5	0.002542	0.000806	0.4596	0.9190	2.34	27.61	0.646	2.43	6.71	
10	0.005228	0.001602	0.9360	1.873	3.31	27.36	0.966	3.44	9.41	
20	0.01037	0.003214	1.946	2.219	4.68	26.88	1.257	4.72	12.69	
40	0.02356	0.007402	4.220	4.812	6.65	26.04	1.732	6.69	17.42	
80	0.05556	0.01749	9.970	11.37	9.485	24.53	2.326	9.56	23.46	
t	$d=0.3$ πd_R	$570\,\pi d_R$	$1140\,\pi d_R$	$\sqrt{570\,\pi d_R t}$	$\frac{28.9}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d}{\sqrt{1+0.003287t}}$		$\sqrt{570\,\pi d_R t}$		
5	0.002417	0.378	2.756	2.79	27.61	8.283	23.1	2.58	20.95	
10	0.004929	2.810	5.620	3.95	27.36	8.208	32.4	3.58	29.29	
20	0.01025	5.842	11.684	5.63	26.88	8.064	45.4	5.07	40.96	
40	0.02210	12.60	25.2	8.07	26.04	7.812	63.1	7.25	56.65	
80	0.05238	29.86	59.72	11.90	24.53	7.359	86.8	10.45	76.9	
t	πd_R	$d=0.5$ $570\,\pi d_R$	$\sqrt{570\,\pi d_R t}$	$\frac{28.9\,d\sqrt{570\,\pi d_R t}}{\sqrt{1+0.003287t}}$	$\sqrt{1140\,\pi d_R t}$	$\frac{28.9\,d\sqrt{1140\,\pi d_R t}}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d}{\sqrt{1+0.003287t}}$	$\frac{28.9\,d}{\sqrt{1+0.003287t}}$		
5	0.002022	2.292	2.70	37.3	4.584	3.09	42.7	27.61	13.81	
10	0.004213	4.682	3.83	52.4	9.364	4.40	60.8	27.36	13.68	
20	0.07787	9.735	5.45	73.26	19.470	6.28	86.8	26.88	13.44	
40	0.03701	21.10	7.82	101.8	42.20	9.07	125.3	26.04	13.02	
80	0.08728	49.76	11.4	139.9	99.52	13.4	185.1	24.53	12.27	
5 (0.07)	0.00566	3.215	2.87	55.47	6.43	3.38	65.34	27.61	19.33	
10	0.01180	6.356	4.04	77.42	12.71	4.77	91.4	27.36	19.16	
20	0.02391	13.63	5.80	109.2	27.26	6.87	129.3	26.88	18.82	
40	0.05182	29.55	8.34	152.1	59.10	9.95	181.4	26.04	18.23	
80 (0.1)	0.1223	69.70	12.25	210.4	139.40	14.8	254.2	24.53	17.17	
5 (0.12)	0.00656	4.593	3.10	85.6	9.18	3.77	104.1	27.61	27.61	
10	0.01643	9.360	4.40	120.4	18.73	5.36	147	27.36	27.32	
20	0.03415	19.46	6.28	169	38.92	7.68	207	26.88	26.88	
40	0.07402	42.20	9.07	236	84.4	11.15	290	26.04	26.04	
80	0.17477	99.58	13.4	329	199.2	16.7	410	24.53	24.53	
5 (0.15)	0.0707	5.74	3.28	113.1	11.48	4.06	140	27.61	34.5	
10	0.02053	11.70	4.66	157.4	23.4	5.78	198	27.36	34.2	
20	0.04269	24.34	6.66	224	48.68	8.29	279	26.88	33.6	
40	0.09254	52.75	9.63	314	105.5	12.1	395	26.04	32.6	
80	0.21820	124.44	14.3	439	248.8	18.1	555	24.53	30.67	

Formulae for wires in still air

Heat generated watts per cm = Heat conducted watts per cm + Heat radiated watts per cm

$$\frac{4c^2\rho\,(1+0.00388T)}{\pi d^3} = 0.00175\,t + m\pi d R_t$$

$$\therefore\ c = 0.886\,d\sqrt{\frac{m\pi d R_t + 0.00175t}{\rho(1+0.00388T)}}$$

for copper 98% cond. $\rho = 1.65\times10^{-6}$ ω.
" bright copper $m = 1$
" blackened " $= 2$

$$\therefore\ c = 28.9\,d\sqrt{\frac{570\,a R_t + t}{1+0.00388T}} \quad \text{bright}$$

$$= 28.9\,d\sqrt{\frac{1140\,a R_t + t}{1+0.00388T}} \quad \text{blackened}$$

where d = diam. wire in cms:
t = temp. elevation
θ = " of surrounding air
T = t + θ the temp. of wire at rest
a = circumference of wire cms
c = current amperes.

If D be measured in inches these become

$$c = 73.4\,D\sqrt{\frac{1450\,a R_t + t}{1+0.00388T}}$$

$$= 73.4\,D\sqrt{\frac{2900\,a R_t + t}{1+0.00388T}}$$

On the winding of a small motor to have ¼ H.P. or 2 man power, to be as light as possible.

The armature to be 6" long 5" diam: and of the drum type.
The e.m.f. to be 50 volts. The thickness of the armature to be ½". The speed to be about 1800 revs: per min.
If an average field of 600 lines be assumed, the peripheral speed is $15.7 \times 2.54 \times 30 = 1200$ cms per sec: so that the length of effective wire will be $50\times10^8 \div 600\times1200 = 5.0\times10^8 \div 7.2\times10^5 = 6.94\times10^3 = 6940$ cms: on each half of the cylinder = 13880 cms: in all. For four amperes at 500 c.m. the drum must be 2000 c.m. thus allowing 2×4 amperes to pass on full load. $\sqrt{2000} = 44.7 = 0.0447$" diam. The nearest B.W.G. is 0.0402" #19 wire which has a res: per foot of 0.00579 ω.

The effective res: of the armature would be $\frac{6940}{2} \times \frac{0.00579}{30} = \frac{6.94\times5.79}{60}\times10^{-3} = 0.68$ ω. The diameter of the wire covered would be 0.042 + 0.020 = 0.062 and the no: of turns possible on the cylinder $\frac{15.7\times1000}{62} = 253$. The effective length has to be 13880 ÷ 30 = 462 feet = 2 layers of wire. The actual resistance would probably be double this effective res: owing to the crossing of the wire = 1.36 ω and the total length of wire would be about 1000 feet = 5.34 lbs.

The magnets will be 6" wide, inclined 14" long and ½" thick. The surface for wire will be 8"×6" = 48 sq. ins. and the ceiling space ½" on each face = 48 × ½ = 24 cubic in:. To allow one 2 ampere to pass, the res: must be 25 ω and allowing 500 c.m. = 1000 cm. = 0.0332" diam = #29 wire the res: of this would be too high $24 \div (d^2 + 0.018)^2$ = length in inches = #23 B.W.G. = 0.0565 ω per ω = 1500 feet = 1400 turns 0.014" covered diam = 56" lineal = 7 layers = ¼" high. = 25 × 0.114 = 3.8 lbs of wire = 2800 ampere turns

Carrying Capacity of wires

Tabulated statement of the current required to raise the temperature of bare bright and blackened wire a given amount in still air

Diameter		5°C		10°C		20°C		40°C		80°C		
cms	In	Bright	Blackened	Bright	Blackened	Bright	Blackened	Bright	Blackened	Bright	Blackened	
0.1	0.0394	6.5	6.7	9.1	9.4	12.6	12.8	17.3	17.4	23.3	23.5	Rather in excess convection being too large
0.3	0.118	21.0	23.1	29.4	32.4	41.0	45.4	56.7	63.1	76.9	86.8	
.5	0.199	37.3	42.7	52.4	60.8	73.3	86.8	101.8	125.3	139.9	185.1	
.7	0.2756	55.5	65.3	77.4	91.4	109.2	129	152.	181	210	254	
1.0	0.3937	85.6	104	120	147	169	207	236	290	329	410	
1.25	0.4921	113.	140	159	198	224	279	314	395	439	555	
1.5	0.5904	143	179	201	253	283	357	398	504	558	714	
1.75	0.6889	174	222	246	313	346	441	488	625	684	888	
2.0	0.7873	208	267	293	377	413	532	583	750	819	1070	
2.5	0.9840	280	365	395	516	557	729	788	1035	1110	1470	

	5° 0.002564		10° 0.005226		20° 0.01037		40° 0.02356		80° 0.05556	
t	td	7.4 td	570 td/t	√	c	1100 td/(1+td)	√	c		
0.25										
5	7.5	55.5	67.29	8.21	340	74.29	8.62	357		
10	15	111	135.1	11.6	476	149.1	12.2	501		
20	30	222	271.2	16.5	665	307.4	17.3	698		
40	60	444	547.3	23.4	914	610.6	24.7	965		
1.75										
5	8.75	64.75	77.78	8.82	426	85.81	9.26	447		
10	17.5	129.5	155.9	12.5	599	172.3	13.1	627		
20	35	259	313.1	17.7	832	347.1	18.6	874		
40	70	518	631.8	25.1	1140	705.6	26.6	1210		
2.0										
5	10	74.0	88.2	9.39	518	97.4	9.87	545		
10	20	148	176.7	13.3	728	195.4	14.0	766		
20	40	296	354.9	18.84	1010	393.9	19.85	1067		
40	80	592	716.4	26.8	1400	800.7	28.3	1470		
2.5										
5	12.5	92.5	109	10.45	721	120.4	11.0	759		
10	25	185	218.4	14.8	1010	244.9	15.55	1060		
20	50	370	438.7	20.95	1410	487.3	22.1	1485		
40	100	740	888.5	29.75	1940	1091	33.0	2150		

Calculations of Carrying Capacity of wires.

(20)

t	td/t	570 td/t	√570 td/t	c	1100 td/(1+td)	√1100 td/(1+t)	c	28.9 / √(1+0.00367t)	32.9 / √(1+0.00367t)
0.25									
5°	0.01308	6.89	3.45	143	13.78	4.33	179	27.61	41.4
10°	0.02464	14.05	4.90	201	28.1	6.17	253	27.36	41.04
20°	0.05122	29.2	7.02	283	58.4	8.85	357	26.88	40.32
40°	0.1110	63.3	10.2	398	126.6	12.9	504	26.04	39.06
80°	0.2619	149.	15.15	558	298	19.4	714	24.53	36.80
1.75									
5°	0.01409	8.03	3.61	174	16.06	4.59	222	27.61	48.3
10°	0.02875	16.39	5.14	246	32.78	6.54	313	27.36	47.9
20°	0.05977	34.07	7.35	346	68.14	9.29	441	26.88	47.0
40°	0.1295	73.8	10.7	488	147.6	13.7	625	26.04	45.6
80°	0.3054	174.0	15.95	684	348.0	20.7	888	24.53	42.9
2.0									
5°	0.01611	9.18	3.76	208	18.36	4.83	267	27.61	55.22
10°	0.03284	18.72	5.26	293	37.44	6.89	377	27.36	54.72
20°	0.06833	38.94	7.68	413	77.88	9.89	532	26.88	53.76
40°	0.14480	84.36	11.2	583	168.72	14.4	750	26.04	52.08
80°	0.3491	199.0	14.7	819	398.	21.9	1074	24.53	49.06
2.5									
5°	0.02013	11.47	4.06	280	22.94	5.29	365	27.61	69.03
10°	0.04106	23.41	5.78	395	46.82	7.54	516	27.36	68.4
20°	0.08537	48.66	8.29	557	97.32	10.85	729	26.88	67.2
40°	0.18500	105.5	12.1	788	211.	15.9	1035	26.04	65.1
80°	0.4363	248.7	18.1	1110	497.4	24.0	1470	24.53	61.3

Table of minimum current strength in ampères required to elevate the temperature of bare copper wires in air overhead in calm weather.

Diam		5°C		10°C		20°C		40°C		
	In	Bright	Blackened	Bright	Blackened	Bright	Blackened	Bright	Blackened	
0.1	0.03937	8.4	8.96	14.4	12.0	16.3	16.4	27.4	22.5	0.1
0.3	0.118	35.5	36.9	45.6	50.1	67.6	70.3	93.0	96.9	0.3
0.5	0.197	70.2	73.2	98.4	102.7	137.1	143.1	189	198	0.5
0.7	0.2756	113	123	158	165	220	238	303	319	0.7
1.0	0.3937	189	199	264	276	368	379	507	534	1.0
1.25	0.4921	261	273	366	383	509	536	701	740	1.25
1.5	0.5904	340	357	476	501	665	698	914	965	1.5
1.75	0.6889	426	447	599	627	832	874	1140	1210	1.75
2.0	0.7873	518	545	728	766	1010	1070	1400	1470	2.0
2.5	0.9840	721	759	1010	1060	1410	1485	1940	2150	2.5

Formulae prepared for more general purposes

$$\frac{4K\rho}{\pi d^2(d+2t)^2} = r \times 10^9$$

$$d^2(d+2t)^2 = \frac{4K\rho}{\pi r \times 10^9}$$

$$d(d+2t) = \sqrt{\frac{4\rho}{\pi \times 10^9}} \times \sqrt{\frac{K}{r}}$$

$$= \sqrt{\frac{4 \times 10^{-9}}{3.14}} \times \sqrt{\rho} \times \sqrt{\frac{K}{r}}$$

$$= \sqrt{12.73 \times 10^{-10}} \times \sqrt{\rho} \times \sqrt{\frac{K}{r}}$$

$$= 3.568 \times 10^{-5} \sqrt{\rho} \sqrt{\frac{K}{r}}$$

$$d^2 + 2td + t^2 = t^2 + 3.568 \times 10^{-5} \sqrt{\rho} \sqrt{\frac{K}{r}}$$

$$d + t = \sqrt{t^2 + 3.568 \times 10^{-5} \sqrt{\rho} \sqrt{\frac{K}{r}}}$$

$$d = -t \pm \sqrt{t^2 + 3.568 \times 10^{-5} \sqrt{\rho} \sqrt{\frac{K}{r}}}$$

This is the most general form.

t is the thickness of insulation on the side in cms.
ρ - - specific res. of the conductor at the temp. required in ohm cm
K - - c.c.
r - - ohms

For Copper $\rho = \frac{1850}{1760} = 1.05 \times 10^{-6}$ $\quad \sqrt{\rho} = 4.30 \times 10^{-4}$

$3.568 \times 10^{-5} \times 4.30 = 15.35 \times 10^{-4} = 0.00154$ $\quad$ 0.0015

- German silver t^2 is negligible

$$d = -t + 3.568 \times 10^{-2} \sqrt[4]{\frac{K}{r}}$$

$$= -t + 0.0392 \sqrt[4]{\frac{K}{r}}$$

For german silver $\rho = 2.08 \times 10^{-6}$ $\quad \sqrt{\rho} = 1.4414 \times 10^{-3}$

$3.568 \times 10^{-5} \times 1.4414 = 5.151 \times 10^{-8} = 0.00515$

So that $d = -t \pm \sqrt{\{t^2 + 0.00515 \sqrt{\frac{K}{r}}\}}$

and when t^2 is negligible

$$= -t + 7.177 \times 10^{-2} \sqrt[4]{\frac{K}{r}}$$

$$= -t + 0.0718 \sqrt[4]{\frac{K}{r}}$$

For iron wire $t = 1.25 \times 10^{-2}$ say $\quad \sqrt{\rho}\ 1.1 \times 10^{-3}$

$3.568 \times 10^{-5} \times 1.1 = 4.2748 \times 10^{-5} = 0.00042745$

so that $d = -t \pm \sqrt{\{t^2 + 0.00042745 \sqrt{\frac{K}{r}}\}}$

when t^2 is negligible

$$= -t + 6.54 \times 10^{-2} \sqrt[4]{\frac{K}{r}}$$

$$= -t + 0.0654 \sqrt[4]{\frac{K}{r}}$$

On the winding of a radial Ormilling electromagnet.

The magnet is similar to that described on page 163 preceding record book but has only ½ the breadth.

The quadrants being all in multiple gives $\frac{100}{5} = 20$ volts per slab. The surface of a slab is $6 \times 10 \times 2$ sq. in. = 760 sq. in. As the magnetism is continuously being directed we may allow 0.15 watts per sq. cm. = 1140 watts = 5.7 amperes = 3.5 hrs.

If K be the winding space in c.c.
t - - - thickness of the wire in: in cm.
d - - diameter
ρ - - - ~~specifing~~ hot
r - - total res: in ohms

Then $\frac{K}{(d+t)^2} \times \frac{4\rho}{\pi d^2} = r \times 10^9$

$$\pi(d+t)^2 d^2 = \left(\frac{r \times 10^9}{4K\rho}\right)^{-1} = \frac{4K\rho}{r \times 10^9}$$

$$(d+t)d = \sqrt{\frac{4K\rho}{\pi \times 10 \times 10^9}} = 10^{-4}\sqrt{\frac{4K\rho}{r \times 31.42 \times 10^9}} = 10^{-4}\sqrt{\frac{4K \times 1850}{r \times 31.42}}$$

$$= 10^{-4}\sqrt{235.56 \frac{K}{r}} = 10^{-2}\sqrt{\frac{K}{r}} = 1.53 \times 10^{-3}\sqrt{\frac{K}{r}}$$

$$d^2 + td + \left(\frac{t}{2}\right)^2 = \left(\frac{t}{2}\right)^2 + 1.53 \times 10^{-3} \times \sqrt{\frac{K}{r}}$$

$$d = -\frac{t}{2} \pm \sqrt{\left(\frac{t}{2}\right)^2 + 1.53 \times 10^{-3} \sqrt{\frac{K}{r}}}\}$$

Here $t = 0.02$

$K = 120 \times 0.75 \times 16 \cdot 3g. = 1467.5$ c.c.

$r = 2.67 \quad \therefore \frac{K}{r} = 553.4 \quad \sqrt{} = 23.5 \times 1.53 = 36 \times 10^{-3} = 0.036$ $\quad$ 0.0004 $\quad$ 0.0364

$\sqrt{0.0364} = 0.191 - 0.01 = 0.18$ cm $= 0.072''$ = #15 B.W.G.

which has 500 ft per ℔ = 1100 feet ÷ $\frac{15}{20}$ = 660 turns $\times (0.007'')^2$ = 50.0 sq. in. = 5 layers. ∴ 10 layers of wire = 3750 ampere turns

2.66 × 7.5 lbs. = 20 lbs. of wire on each = 40 lbs. in all.

Result 40 lbs. of #15 B.W.G. wire 0.072" or 20 lbs per slab

Particulars of the winding and average magnetic field in the Edison 120 ~~Cycl~~ volt phonograph motor.

The average number of turns on one block is 1140 and 10 blocks form a complete cycle so that 11400 turns each 3 cms in length or 34200 cms is the total breadth of enclosed area. The diam. is 18 cms or 56.5 circumference 170 turns per min = 2.83 per sec. = 56.5 × 2.83 = 160 cm per sec. and the e.m.f. being 8.8 volts see p. 118 both III

$$f = \frac{8.8 \times 10^8}{1.60 \times 10^{-8} \times 34.2 \times 10^3} = \frac{8.8}{6.71} \times 10^3 = 1.31 \times 10^3 = 13 \text{ Gauss}$$

Calculation of the winding for a Brake bar motor on the Quadripolar plan.

The armature to have an external diam. of 7" (17.8 cm)
" internal diam. 5 3/4" = (14.6 cm), the depth 2" (5.1 cm)
and the breadth 5/8" (1.6 cm)
The velocity to be 1200 revs. per min = 20 per sec
$= 20 \times \pi \times 17.8 = 20 \times 55.9 = 1118$ cm per sec.
The breadth $= 5.2$ in
$\therefore 5.2\text{in} \times 1118 = 50 \times 10^5$

$\therefore n = 5.0 \times 10^5 / 5810 \times 10^3 = 8.60 \times 10^5$

If now we take the average field to be double that in the phonograph field namely 2×13 gauss $= 2600 = 2.6 \times 10^3$

Then $\frac{8.6}{2.6} \times 10^2 = 330$ turns. $= 1320$ turns of wire in all.

With the present phonograph armature with pacinotti teeth, this would represent 4 layers of their present wire 0.034"

The coiling space of the wire on any block is $2 \times 2" \times 3\frac{1}{2} \times \frac{1}{2}" = 7$ cubic in $= 114.8$ c.c. All four in series shall have 50 revs. or 12.5 revs each

$$\therefore d = -\frac{t}{2} + \sqrt{\left(\frac{t}{2}\right)^2 + 0.00153 \sqrt{\frac{114.8}{12.5}}}$$

$$= -0.0[illegible] + \sqrt{\{0.00[illegible] + 0.00153 \times 3.80\}}$$

$$\sqrt{0.00[illegible] + 0.0058}$$

$$\sqrt{0.0060}$$

$$0.077 \text{ cm.}$$

$$= 0.069 \text{ cm} = 0.0275" = \# 22 \text{ BWG. } 0.026"$$

which has 0.18 lbs per ft = 9 lbs of wire.

Taking half the coiling space

$$d = -0.038 + \sqrt{\{0.0002 + 0.00153 \times 2.6\}}$$

$$+ \sqrt{0.0002 + 0.004}$$

$$+ \sqrt{0.00402}$$

$$+ 0.063 \text{ cm}$$

$$0.057 \text{ cm} = 0.023" = \# 24 \text{ BWG}$$

which has 0.069 lbs per ft $\equiv$ 3.45 lbs

23 BWG. has 0.1145 lbs per ft = 5.72 lbs of wire or 1.43 lbs on each limb.
= 520 ft per lb = 7579 = 760 feet. The mean turn is $7\frac{1}{2}$" = Around this wire has diam 0.037" = 54 turns to the layer and 1200 turns = 22 layers. = 0.81"

Actually wound 17 oz of # 23 wire on each limb to economise space.

On first running this motor on the 21st September, it made 1050 revs. per min: @ 50 volts on M.T. with 8 amperes of which about 1 ampere would be in the field.

The armature wire is # 23 BWG = 0.025" = 625 c.mil = 2500 cm in all = 312 cm in all

Inductance of a triple coil.

August 17th Saturday

Took the following measurements of the inductance in a small coil whose dimensions were as follows:-

Length 11 cms diam 3·8 cet; 1·4 int.

Primary 0·39 m Secondary 130 m Tertiary 4·30 m.

No.	Bridge	Res. ohs	Capacity	Primary	Secondary.	Inductance Henrys	Henries	Mutual		
1	100/m	129·38	0·37	heated	disc.	0·0479	479			
2		436·5	0·248	disc.	heated	0·1083	1083			
3		436·8	0·088	in batty ct.	"	0·0384	384	0·0699 Mut	0·0636	636
4		436·55	0·405	" - - same	-	0·1768	1768	0·0685	0·0623	623
5		129·62	0·905	heated	in batty ct.	0·1173	1173	0·0694	0·0631	631
6		129·62	negative	"	" - - same	—	-			

Particulars concerning the Niagara Falls.

The contour on the American fall is stated to be 1060 feet
" " " " Canadian " " " " 2640 "
" total fall of water is estimated at 265,000 cubic ft per sec.
" fall on the Canadian side 162 ft
" " " " American " 158 "
" velocity of the stream below the cantilever passenger bridge and the first bend of the stream in the rapids was about 23 miles per hour, a log traversing 540 yards in 55 secs. The log was dropped from the centre of the bridge and appeared to take 5 seconds to reach the water, the height of the bridge being stated at 248 feet

---

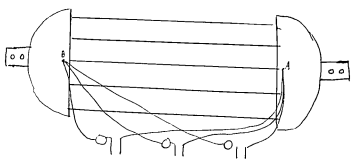
1 cubic foot of water weighs about 62·4 lbs.
So that on the above estimate the weight of water falling per second is 16,536,000 lbs a distance of 160 feet = 2646 million ft-lbs. per second = 4·81 million horse power.

Copy of test of three meters by Mr A. B. Herrick. 28th Nov. 89

1200 ampere R. 0·000333 ω legal

Shunt composed of four strips of special german silver made by Lovell Mfg Co
Each 0·1" thick 6" wide and 52·64" long.
Mounted in massive brass castings and same as 800 ampere shunt
Each shunt carried 300 ampere R = 0·001333 legal ω @ 45°C.
which was temp. obtained after carrying load for one hour.
The drop was then taken & compared with Daniell & Black standards = 0·4 volts
The compensating spools were 46·46 L.ω. @ 70°F.

800 ampere R. 0·0005 ω legal
This shunt was composed of four sheets of special german silver made by Lovell Mfg. Co.
Each 0·0625" thick. 6" wide 67·3125" long.
Mounted in massive brass castings 90% copper 10% tin
Each strip 200 ampere
R. = 0·000125 ω legal @ 38·5°C.
After carrying full load for 1 hour temperature became constant
The final drop test was taken at points A & B. and gave 0·4 volts compared with both standard Daniell & Black.
The three spools each measured 46·46 legal @ 70°F
Connecting wire was so large that its resistance was not appreciable



Each meter deposits 10 milligrammes of zinc for each hour on full load.

The temperatures of the strips carrying 300 ampere each before blackening were

1" × 6" × 67"	Bright	300 ampere	Time 30 mins.	55°C.
" " "	Blackened	"	" 60 "	48°C.

Normal temp. 21°C.

(24)

Calculations for the dimensions of two Edison meters of 800 & 1200 ampere capacity for Mr Beatty & Sons. of Covent Garden London

The large laboratory platinoid shunt is composed of 4 strips each 7 × 22 ¾" (7·58 cms) long 6" (15·2 cms) broad and 0·062" (0·1625 cm) thick and the total res. is 0·001627 ω when all are in series. so that neglecting the res. of the intermediate large pillar, the resistivity is

$$\frac{4 \times 1.627 \times 10^{-3} \times 15.24 \times 0.1625}{4.06 \times 10^{-2}} = 39.7 \times 10^{-6}$$

so that the resistivity of platinoid is practically 40 microhms ω result corroborated by several other measurements.

The rise of temp. in this shunt was very small when 300 ampere passed through it, that is when $3.0 \times 3.0 \times 10^{-6} \times 1.627 \times 10^{-3}$ or 14·5 Watts were generated in it. Its surface being 58 × 2 × 4 × 7 or 3250 sq. cms. i.e. 22·3 sq. cms. per Watt.

All the new Edison meters are designed for a fall of 0·4 volts p.d. ω full load, and if that be taken for the 1200 amp. meter, the energy at full load will be 4·80 Watts and this approximately 10,000 sq. cms in total surface.

If l to the length of ω single meter strip
b - - breadth
t - - thickness } cms
r - - resistance
ρ - - resistivity
s - - surface
Then $2bl = s$ ω constant

$$\frac{l\rho}{bt} = r \quad \text{ω} \quad = \frac{s\rho}{2bt} = \frac{2l^2\rho}{st}$$

$$\therefore lbt = v \text{ the volume of metal} = \frac{st}{2}$$

$$t = \frac{s\rho}{2b^2 r} = \frac{2l^2\rho}{rs}$$

$$v = \frac{s^2\rho}{4b^2 r} = \frac{l^4\rho s}{r}$$

so that $v \propto l^4$

In this case $s = 10{,}000 = 1.0 \times 10^4$
$\rho = 4.0 \times 10^{-6} = 4.0 \times 10^{-5}$
$r = \frac{4}{12{,}000} = \frac{1}{3000} = \frac{1}{3} \times 10^{-3}$

If $l = 100$ $b = 50$ $l^4 = 10000 = 1.0 \times 10^{-4}$ ω 1200 $t = 0.24$ cm $= 0.096"$
$= 80$ $b = 62.5$ $l^4 = 6400 = 6.4 \times 10^{-3}$ ω 765 $t = 0.153$ " $= 0.061"$
$= 120$ $b = 41.75$ $l^4 = 14{,}400 = 1.44 \times 10^{-4}$ ω $v = t = 0.345$ " $= 0.1340"$

At 40° temp. elevation, the radiation will be 0·02356 Watt per sq. cm. × 2 and the convection 100 × 40 × 0·00175 = 7·0
∴ 10000 × 0·047 = 470 + 7 = 477 Watts. when blackened.

With 48·96 in spool & small bottle, the deposit will be 1 mgm. per hour for 120 ampere. and an oxidation of 15 mgms per plate will make a monthly error of 6000 ampere or 8½ hrs. of full load.

With 800 ampères, the energy developed will be $0.4 \times 800 = 320$ Watts at full load, and the resistance will be $\frac{0.4}{800} = \frac{1}{2000} = 0.0005\,\omega = 5.0 \times 10^{-4}$, the area @ 20 sq. cms. per Watt = 6400 sq. cms.

$\therefore t = \frac{2\,l^2 \rho}{r^3}$

If $l = 100$ $b = 32$ $l^2 = 1.0 \times 10^4$ $r = 800$ $t = 0.25$ cm $= 0.100''$.
" $l = 80$ " 40 $l^2 = 6.4 \times 10^3$ $r = 512$ $t = 0.16$ " $= 0.064''$

With 28.96 in bottle circuit 1 mgm is deposited per hour with 200 ampères, so that an error of 5 mgm oxidation per month will represent 400 ampère hours = ½ his full load.

Frequency measurement by the method of Ayrton & Perry

Alternating Dynamo running at 1535 revs per min = 25.7 per second = 2056 alternations or 102.8 ~ per sec.

Joined up an electro magnet on the 100 volt cct, and ran an iron wire between its poles. The alternating current ran through this wire. It was 0.011" = .02798 say 0.028 cms. in diam. The free length when in full vibration was 37½" (95.25 cms) and the tension was 1,500 grammes. The weight of the sonometer wire was 0.07125 grammes per cm. so that from the formula $n = \frac{1}{2l}\sqrt{\frac{f}{m}}$

$l = 95.25$ $2l = 190.5$
$f = 1500 \times 980.2 = 1479000 = 1.47 \times 10^6$ $\frac{f}{m} = \frac{6.335}{3.266} \times 10^8 \sqrt{} = 1.807 \times 10^4$
$m = \cancel{0.07250}\ 0.0045 = 4.5 \times 10^{-3} = \cancel{7.25} \times 10^{-2}$

$1.807 \times 10^4 \div 1.905 \times 10^2 = 9.49 \times 10^1 = 94.9$ complete vibs. per sec.

By means of Helmholtz Resonators, the tone was traced to R_2# D has 72.144 complete periods per sec. $\frac{\cancel{64.5} \times 313.2}{261} = \cancel{76.5}$ 76.5 complete vibs per sec. Taking DT as 8192 single vibrations per sec. $\frac{102}{76.5} = \frac{4}{3}$ = major fourth above or fifth below. It is thus probable that a mistake was made in taking the note as R_2# instead of I_2.

Heat in the magnet of a # 20 dynamo
The E.M.F. of this dynamo being 125 volts and the field magnets having 22ω res. the energy developed at full load in them is $(125)^2/22 = 710$ Watts.
The diameter of one magnet is externally 17¾" = 44.2 cms + circ = 139
length of the field coil is 24" = 60.8 cms
total radiating surface = 60.8 × 139 × 2 = 16,900 and the area per watt = 23.8 say 24 sq. cms.

If the current be 8 ampere and the pressure be 50 volts the energy will be 400 Watt. The radiating coil surface is

$2\pi \times 1\tfrac{1}{2} \times 9.3 + \pi \times 12 \times 10.5$

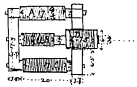
$= 103.4 + 396 = 1430$ sq cms. and allowing 10 watts per sq. cm. ~~for convection~~ = 143 Watts, practically 3 amperes. The total resistance must therefore be $\frac{50}{3} = 16.67\,\Omega$

16⅔ ft of # 19 BWG @ 5.23 lbs per ft = 87.22 lbs in all.
409.29 ft . . = 6820 ft

$\frac{6820 \times 6.48}{23.14} = 1910$ ft on the central core and thus $4910 \div 2 = 2455$ on each outside.
2455 ft = 74880 cms. Round, this wire will have a diam. of 0.080" = 0.2 cms. and there will be 7.5 layers of 89 turns each = 670 turns of mean diam. 7.8 cms. = $670 \times 3.14 \times 7.5 =$
16⅔ ft of # 19 BWG @ 0.913 lbs per ft = 15.2 lbs in all
16⅔ . . . a 170.9 ft . . = 2850 ft

$\frac{2850 \times 6.48}{23.14} = 798$ ft on central core and thus $2850/2 = 1025$ ft on each outside core = 31260 cms. Round, this wire will have a diam. of 0.1145 cms. which means 122 turns and 10 layers = 1220 turns of mean circumference 24.5 cms = 29.900 cm
On the central core there will be 10 layers and $12 \times \frac{1}{0.1145} = 83$ turns = 830 turns

The following are the particulars of this experimental apparatus as at present in use.



Res. of coil A = 7.09 Ω @ 24.°C copper wire 0.026" abt # 22 BWG and offering 2 cms 60 feet per Ω = 4.25 ft = 12960 cms. @ 4.1 mean diam = 129 per turn = 1000 turns diam. of wire covered = 0.041" = 0.103 cms and about 6 layers of 170 turns each.

" " B = 7.37 Ω @ 24.°C same wire = 4.40 ft = 13400 cms = about 1040 turns.

" " D = 1.49 Ω @ 24°C copper wire 0.0240 # 18 B.W.G. about 40 feet per Ω = 205 ft = 6250 cms @ mean diam. of 5 cms = 15.7 per turn = 400 turns = 8 layers of 50 turns and diam. of wire covered = 0.056" = 0.14 cms

" " C = 4.67 Ω @ 24.°C 0.024" diam wire = 2250 = 680 turns

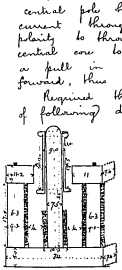
The three field coils were put in series, and a current of 0.51/0.195 or 2.62 ampere passed through them making an exciting power of $2.62\,(650 + 1000 + 1040) = 2.62 \times 2690 = 7050$ ampere turns.

The armature had a current of 1.6/0.195 = 8.21 ampere making an exciting power of $8.21 \times 400 = 3280$ ampere turns.

Under these circumstances, the weight which the armature would lift through a range of 4 cms was 2765 grammes (supported by a wire over a pulley). The work done would thus be 11100 cm. gms. at a stroke. Neglecting at present the effect of a reversal of current in doing work by accelerating the return it would be necessary to repeat the stroke $\frac{746}{1.09}$ or nearly 700 times per sec. to obtain a H.P., and $\frac{1000}{1.09}$ or more than 900 times per sec to realize a Kilowatt.

The two outside field poles are of the same name, and the central pole has the opposite name. The effect of putting the current through the armature is when it strengthens the central polarity to throw a large amount of force from the end of the central core to the outside poles, and these lines of force exerting a pull in the direction of their length carry the armature forward, thus shortening the magnetic circuit.

Required the winding for an apparatus on the same principles of following dimensions.


17.9
10.5
11
7.8
9.3
1.5
2.5
2.5
1.5
2.5
2.5
1.5
2.5
2.5

The armature will have a surface of $\pi \times 13 \times 17.5$ sq. cms = 715 sq. cms and allowing 3 sq. cms per Watt since the armature is in motion, gives 240 Watts. at 50 volts this is about 5 amperes. and the res. of the coil must therefore be 10ω, but as with the intended speed the counter. e.m.f. helped for is considerable, we may commence with the estimate of 5ω.

The ceiling space is

$$\frac{\pi}{4} \times 17.5 \times (13^2 - 9^2)$$
$$= \pi \times 4.375 \times (169 - 81)$$
$$= 3.142 \times 4.375 \times 8.8 \times 10$$
$$= 1210 \text{ c.c.}$$

$$\therefore \quad d = -0.02 + \sqrt{\left\{0.00014 + 0.00153\sqrt{\frac{1210}{5}}\right\}}$$
$$+ \sqrt{\left\{0.00014 + 0.00153\sqrt{242}\right\}}$$
$$+ 0.00153 \times 15.56$$
$$+ 0.0238$$
$$+ \sqrt{0.0242}$$
$$+ 0.156$$
$$= 0.136 \text{ cms} = 0.054''$$

Nearest to this is # 17 B.W.G. 0.058" wire = 0.1466 cm. and covered 0.186

There will thus be $17.5/0.19 = 92$ turns and $\frac{2.0}{0.19} = 11$ layers

= 1012 ampère turns × current.

To obtain seven times the pull of the experimental apparatus we may estimate that seven times the no. of ampère turns will be needed viz 7 × 3280 = 22960 so that on that reckoning 22 amperes will be required to drive it.

The diam. of the mean turn = 11 cms.
diameter. = 34.6 cms.

1012 × 34.6 = 35100 cms. = 1150 feet. × 0.0102 = 11.5 lbs.

5ω × 3.317 = 16.5 lbs. but this is excessive because the wire is 6 layers.

12 lbs of # 17 B.W.G. will be the result.

Measurement of Inductance.

A reel holding 52 lbs or about 1400 feet = 42700 cms. of # 12 B.W.G. S.C.C. black magnet wire diam: 0.109" = .0277 and covered to 0.125" = 0.318 cm. was wound on a reel 25 cms: in diam: and 13.5 cms wide to a Mean diameter of 38.35 cms. a depth of 4.5 cms. It was then measured as follows:-

22. 8. 89. Res. 1000/100 1.4070 including lead 0.1 3.95 ft = 0.0556 ω = .556 kilometres. This wire was not closely wound on the reel. The insertion of a steel bar about 2 cms thick into the centre so as to carry the reel increased the inductance to 0.06650

This wire was then wound to a depth of 3 cms upon a flat wooden board 82 × 15 × 5.5 cms there being 5½ layers. The measurement of the coil (light) wound under these conditions gave the Res: without leads 1.377 $\frac{1000}{100}$ 1.7 ft = 0.0240 ω showing the effect of changing the form of a coil.

In another case the wire on spool had a res: of 1.4425 ω without leads and an inductance of 1.4425 × 0.03888 = 0.0583 ω

In a third case the values were 1.4415 + 1.4415 × 0.03925 = 0.0555 ω

In a fourth case the flat coil removed from its board + slightly distorted gave 1.4448 ω + 1.4448 × 0.01145 = 0.0210 ω

Observations of Sun for obtaining time
22nd August 89 Thursday

At $16^h.\ 19^m.\ 0^s$ Astronomical Clock Time, the observed hour angle was $66°.\ 19'$ or in time $4^h\ 25^m\ 16^s$.
At Gov. noon the equation of time was $2^m.38^s$

Longitude W. $4.\ 56.\ 34$
Hour angle $4.\ 20$
$9.\ 16.\ 34$ = $\frac{9.27 \text{ hour} \times 16}{24}$ = 6.3s subtractive

so that the equation of time was $2^m\ 32^s$ to be added to apparent time.

$4.\ 25.\ 16$
$2.\ 32$
$4.\ 27.\ 48$ True local time.
W of N.Y. $1.\ 00$
$4.\ 28.\ 48$ True N. Y. Mean time

2nd trial. At 16.36.0 Astronomical clock time, the observed hour angle was $64°.\ 4.\ 30'$ or in time $4.\ 32.\ 2$
the apparent elevation 24° the declination 11°.33'.
the equation of time $2.\ 32$
$4.\ 34.\ 34$ Local time
$1.\ 00$
$4.\ 35.\ 34$ N.Y. Mean time

Clock error 36 seconds fast.
The 2nd trial was much more reliable than the first
the magnetic declination appeared to be 7°.30' W.

Record of a Trial made on the 31st Aug: 89
of the effect of a magnetic field on the heart's action

The armature of the # 20 Dynamo was removed, and the fields were charged by the 2 # 10s giving about 210 volt. Three persons, Atwood Lehmann & self were experimented upon. The subject rested on boards with his head well within the polar cavity and with the occipital protuberance downwards supported on a wooden block. The eyes were kept closed, while the sphygmograph tracing was taken of the radial pulse of the left arm. In the middle of the tracing the fields were suddenly excited. The tracings were not very successful partly owing to the influence of the magnetism on the steel needle point, but so far as could be observed there was no effect produced, and no sensation could be recognized.

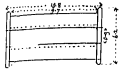
The field was explored by means of the frame mentioned on page 68 Record book VI. The throw in the center of the polar space was 23 that from 1.43×10^{-7} being 107

$$\therefore \mathcal{E} = \frac{23}{107}\left(\frac{5.344 \times 1.43 \times 10^5}{3.77 \times 10^2}\right) = \frac{175.7 \times 10^5}{403.4 \times 10^2} = 436 \quad 43 \text{ Gauss}$$

Inductance Measurements

August 23rd Friday

Took the following measurement with an induction coil without iron core, having four coils and the following dimensions.



P 16 turns coil 4 layers of copper wire covered to 0.0144" = 0.1 on Rm. 056.
S One " 4 " " " " 0.0216" = 0.1 " 0.66.
T One " 9 " " " " 0.032" = 0.08" " 1.67.
a One " 20 " " " " 0.038 = 0.095 " 3307.

No. of obs.	Coil tested	Res: ohms	Cont. on batty cat:	Bridge note	Permittance μ	Inductance Henries	Inductance Kilometer	Mutual Inductance Henries	Mutual Inductance Kilometer	$\frac{L}{R}$ $\frac{L}{R+1}$
1	P	0.492	none	1000/10	0.618	0.000305	3.047			3.05
2	S	0.679	"	"	0.960	0.000652	6.518			6.5
3	T	167.1	"	1000/100	0.410	0.0685	6.850			685
4	a	3205	"	1000/100	0.492	1.626	16.260			16.230
5	a	3307.2	T	1000/100	0.330	1.091	10.910	0.535	5350	
6	"	3307.8	" reversed	"	0.651	2.154	21.540	0.527	5270	~~5320~~ 2660
7	" reversed	3307.9	" ——	"	0.326	1.079	10790	0.547	5470	
8	" ——	3308.7	"	"	0.648	2.144	21.440	0.518	5180	
9	a	3309.8	S	1000/100	0.500	1.655	16.550	0.029	290	
10	——	3310.1	" reversed	"	0.479	1.586	15.860	0.030	300	
11	—— reversed	3311.2	" ——	"	0.500	1.656	16.560	0.030	300	~~300~~ 150
12	—— ——	3311.6	"	"	0.479	1.586	15860	0.030	300	
13	a	3309.8	P	1000/100	0.485	1.606	16.060	0.0165	165	
14	——	3310.2	" reversed	"	0.495	1.639	16.390	0.0165	165	
15	—— reversed	3310.4	" "	"	0.485	1.606	16.060	0.0165	165	~~165~~ 82.5
16	—— ——	3310.6	——	"	0.495	1.639	16.390	0.0165	165	
17	T	167.3	a	1000/100	2.170	03631	3631	0.2948	2.948	
18	" reversed	167.5	" reversed	"	2.170	0.3635	3635	0.295	2.950	~~2.948~~ 1.480
19	T	167.8	S	1000/100	0.443	0.0743	743	0.0058	58.0	
20	"	167.8	S. reversed	"	0.373	0.0626	626	0.00589	59.0	
21	" reversed	168.5	S ——	"	0.443	0.0746	746	0.00614	61.4	~~58.25~~ 5.295
22	——	168.8	" "	"	0.373	0.0630	630	0.0055	55.0	
23	S	0.683	P	1000/10	1.440	0.000983	9.832	0.000331	3.314	
24	"	0.683	" reversed	"	0.455	0.000311	3.109	0.000341	3.410	
25	" reversed	0.684	" ——	"	1.445	0.000985	9.885	0.000336	3.367	~~3.374~~
26	" ——	0.684	"	"	0.455	0.000313	3.113	0.000340	3.405	~~3.334~~
27	P	0.504	S	1000/10	1.270	0.000544	5.440	0.000335	3.353	~~3.353~~ 3.353

Results

Coil	Res:	L Inductance	M: Inductance with P	S	T	a	Kilometer
P	0.504	3.047		3.33			
S	0.683	6.518	3.33		52.95	150	
T	167	685		52.95		2670	
a	3205	16260	82.5	150	2670		

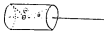
Magnetic Data

Magnetic moment	ml		$L^{\frac{5}{2}} M^{\frac{1}{2}} T^{-1}$
Magnetic mass, strength of pole, quantity of magnetism or magnetic flux of force	$\frac{\mu l d}{r} = m$		$L^{\frac{3}{2}} M^{\frac{1}{2}} T^{-1}$ {current in E.S.units mult. by 1 Sec. = electromagnetic unit}
Magnetic potential, (work or mass) magnetomotive force of solenoid (ampere)		P	$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$ {EMF in E.S.units mult. by current in E.M.units}
Intensity of magnetization $\frac{ml}{V} = \frac{m}{s}$ or the magnetizing force of a solenoid $\frac{4\pi n c}{l}$ or the intensity of field $\frac{m}{s^2} = H = \mathcal{E}$		H	$L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$
Reluctance $= \frac{P}{\phi} = R$		R	L^{-1}
Reluctancy ρ $(R = \rho\frac{l}{s})$ $= \frac{H}{B}$		ρ	numeric.

$\mu = 1 + 4\pi K.$

Exciting power = ampere turns/μ = nc.

The magnetic field at any point distant l from a straight conductor carrying a current c is $\mathcal{E}$ $\frac{4\pi c}{l}$ where ϕ is the angle subtended at the point by the conductor. If this total field the component acting parallel to the conductor length is $\frac{c}{l}(\sin\theta_1 + \sin\theta_2)$ where θ_1 and θ_2 are the angles subtended on each side of the perpendicular let fall from the point to the current at l.



(at any point O on the axis or of an cylinder carrying a current uniformly) i.e. a solenoid of current c per unit of length the field will be $2\pi c\,(\cos\theta - \cos\theta)$ so that for an infinite solenoid the field is $H = 4\pi c = \frac{4\pi C}{l}$ and the total flux $= \frac{4\pi C}{l}$ or $\frac{4\pi nt}{l}$ where n is the current and n the total no of turns.

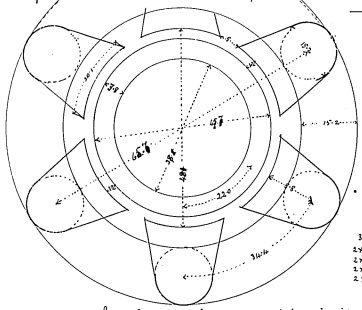
It is thus evident that considering a solenoid without iron core the effect of winding on a cylinder of larger diameter is to increase the total flux for $\frac{d\phi}{dt} = \frac{d\phi}{da} \times \frac{da}{dt} = 2\pi \times \left\{ \frac{4\pi n i}{l} + \frac{4\pi a i}{l} \times \frac{\pi}{4\pi a} \right\}$

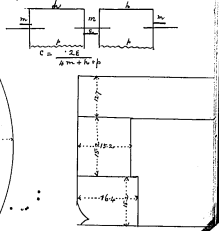
$$= 2\pi \left\{ \frac{4\pi n i}{l} + \frac{i}{4} \right\}$$

for which the turns diminish in number with the radius the area increases with the square of the radius. This applies only however to closed solenoids or where the reluctance of external air is small

Calculation of Induction in the sextipolar transformer

The dimensions of this machine in so far as relates to its magnetic conditions are as follows:—





36·4 − 7·6	=	26·8
2 × 6·4	=	12·8
2 × 15·2	=	30·4
2 × 7·6	=	15·2
2 × 10·	=	20
		105·2

The mean length of the magnetic circuit is in the field magnet allowing 5% reduction = 100 cms.

" " " " " " circuit in the armature = 12 "

" " area of cast iron in the cores is 181·5 sq cms. in each lot.

" " " " " " " " pole . . . 90·7

" " " " " " " " pole . . . 130

" " " " " " " " ring . . . 190

If ρ be the reluctancy of the cast iron. Then the reluctance $r = \rho\left(\frac{26}{190}\right) + \rho\left(\frac{15.2}{90}\right) + \rho\left(\frac{20}{130}\right) = \rho\{0.137 + 0.622 + 0.1538\}$

$= \rho\,(0.913)$

If also ρ_1 be the reluctancy of the wire armature, the reluctance

$= \rho_1 \frac{22}{12.7 \times 3.9} = \rho_1\left(\frac{22}{49.26}\right) = 0.446\,\rho_1$

If also ρ_2 be the reluctancy of the air, then the reluctance of the air

$= \rho_2(0.1456)$

$= 2\rho_2 \times \frac{2}{12.7 \times 10} \cdot \rho_2 \frac{3.4}{12.7} = 0.0189$

$= \rho_2\,(0.0189) = 0.0189$

The {permeability} of cast iron may be taken roughly as 500, and that of the wire armature as 750 for trial values. then

$$R = \frac{0.913}{500} + \frac{0.1456}{750} + 0.0189$$

$$= 0.001826 + 0.000601 + 0.0189$$

$$= 0.02133$$

On each limb of the magnets there are 16 lbs of #23 B.W.G. 0.025"

= 528·5 × 16 = 8460 ft = 257,800 cms. = 1100 "

The internal diam of the core is 15·5 = 46·7 cms. inc.

" external circumference 64·5 "

" mean " 56·6 " = 1·856 ft. nearly

25780 ÷ 56·6 = 4550 turns

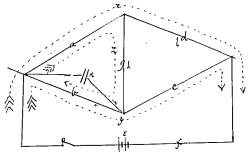
Measured res: of each limb about 160 ω

With 130 volts the current would be 0·812 amp

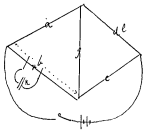
Ampere turns on each limb = 3697 Exciting power = 4650 per limb

= 9300 " pair

vide p. 35

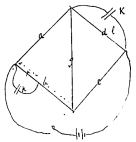


Rimington's amended form



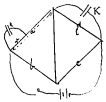
$$l = +kd\left(\frac{r}{b}\right)$$

See Vol. XXX No. 515 Oct. 7. 97 "Electrical Review" London



$$l - Kd^2 = +kd\left(\frac{r}{b}\right)$$

$$l = Kd^2 + kd\left(\frac{r}{b}\right)$$



$$l = Kd^2 - kd\left(\frac{r}{b}\right)$$

Mathematical Treatment of Inductance Measurements.

In the opposite diagram a b c d is a wheatstone bridge, of which d is the arm whose inductance l is to be measured. The other arms having negligible inductance. g is the galvanometer of inductance λ, ε is the testing emf with a res. of f in its circuit, and the currents in the net work are x, y and z.

Then at any moment after closing the key.

(1) $\varepsilon = f(x+y) + a(x+z) + dx + l\frac{dx}{dt}$

(2) $\varepsilon = f(x+y) + b(y-z) + cy$ where q is the charge on condenser k at any instant.

(3) $-\lambda\frac{dz}{dt} = a(x+z) + gz + b(z-y) + \frac{dq}{dt}$

$$\begin{array}{cccc} & (x) & (y) & (z) \\ \left| \begin{array}{c} a+d+f \\ f \\ a \end{array} \right. & \begin{array}{c} f \\ b+c+f \\ -b \end{array} & \begin{array}{c} a \\ -b \\ a+b+g \end{array} \left. \right| & \begin{array}{l} = \varepsilon - l\frac{dx}{dt} \\ = \varepsilon + b\frac{dy}{dt} \\ = -\lambda\frac{dz}{dt} * - b\frac{dy}{dt} \end{array} \end{array}$$

$$\therefore \Delta z = \begin{vmatrix} \varepsilon - l\frac{dx}{dt} & a+d+f & f \\ \varepsilon + b\frac{dy}{dt} & f & b+c+f \\ -b\frac{dy}{dt} - \lambda\frac{dz}{dt} & a & -b \end{vmatrix}$$

where Δ stands for the principal determinant

$$* = \begin{vmatrix} \varepsilon & a+d+f & f \\ \varepsilon & f & b+c+f \\ 0 & a & -b \end{vmatrix} - l\frac{dx}{dt}\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} - b\frac{dy}{dt}\left\{\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix} + \begin{vmatrix} a+d+f & f \\ f & b+c+f \end{vmatrix}\right\}$$

$$- \lambda\frac{dz}{dt}\begin{vmatrix} a+d+f & f \\ f & b+c+f \end{vmatrix}$$

$$\Delta z = A - B\frac{dx}{dt} - C\frac{dy}{dt} - D\frac{dz}{dt}$$

Multiplying by dt + integrating between $t = 0$ and $t = T$

$$\Delta\int_0^T z\,dt = A\int_0^T dt - B\int_0^x dx - C\int_0^a dy - D\int_0^z dz$$

The left hand term integral is by adjustment zero, since balance is obtained by the condenser K for both steady and variable currents.

A is identically 0.

the B integral is x the final steady current value

the C - - a - - - condenser charge $= Kax$

- D - - necessarily 0.

$$\therefore \quad 0 = -Bx - CKax \quad \text{or} \quad -B = +CKa.$$

$$\therefore \quad l\,(bf + ab + ac + af) = kbab\left(\frac{x}{a}b + ac + \frac{x}{a}f + \frac{x}{a}bf + cd + df + \frac{x}{a}cf + \frac{x}{a}bf + \frac{x^2}{a^2} - \frac{x}{a}b - \frac{x}{a}f - \frac{x}{a}b\right)$$

$$= kbab\,(ac + cd + df + cf)$$

$d = ma$

$c = mb$

$$l(bf + ab + amb + af) = kbab\,(amb + amb + amf + bmf)$$

$$= kamb\,(ab + amb + af + bf)$$

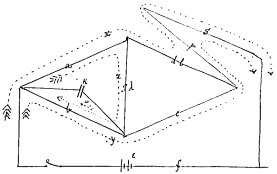
$$\therefore \quad l = kamb$$

$$= kac$$

$$= kbd$$

Maxwell's formula.

Rimington has shewn that if with an unadjustable condenser, K the balance be obtained by throwing k as a shunt round a portion r of the res: b, then $l = kd\left(\frac{r}{b}\right)$



Mathematical Treatment of Mutual Inductance measurement.

With the same notation as on the previous page, let s be a coil having a self inductance of s and a mutual inductance of μ. Then at any instant after closing the battery circuit we have.

$$\varepsilon = f(x+y) + a(x+z) + dx + (l \pm \mu)\frac{dx}{dt} + (s \pm \mu)\frac{d(x+y)}{dt} \qquad (1)$$

$$\varepsilon = f(x+y) + b(y-z-\frac{dy}{dt}) + cy + s\frac{d(x+y)}{dt} \pm \mu\frac{dx}{dt} \qquad (2)$$

$$-\lambda\frac{dz}{dt} = a(x+z) + gz + b(z-y+\frac{dy}{dt}) \qquad (3)$$

From these equations we obtain a determinant for x y z

$$\begin{matrix} a+d+f & f & a & = & \varepsilon - \frac{dx}{dt}(l \pm \mu + s) - \frac{dy}{dt}(s \pm \mu) \\ f & b+c+f & -b & = & \varepsilon - \frac{dx}{dt}(s \pm \mu) - s\frac{dy}{dt} + b\frac{dy}{dt} \\ a & -b & a+b+g & = & -b\frac{dy}{dt} - \lambda\frac{dz}{dt} \end{matrix}$$

so that

$$\Delta z = \begin{vmatrix} \varepsilon - \frac{dx}{dt}(l \pm \mu + s) & -\frac{dy}{dt}(s \pm \mu) & a+d+f & f \\ \varepsilon - \frac{dx}{dt}(s \pm \mu) & -s\frac{dy}{dt} + b\frac{dy}{dt} & f & b+c+f \\ -b\frac{dy}{dt} & -\lambda\frac{dz}{dt} & a & -b \end{vmatrix}$$

$$\therefore \Delta z = \begin{vmatrix} \varepsilon & a+d+f & f \\ \varepsilon & f & b+c+f \\ 0 & a & -b \end{vmatrix} + \frac{dx}{dt}\left\{-(l \pm \mu + s)\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} + (s \pm \mu)\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix}\right\}$$

$$+ \frac{dy}{dt}\left\{-(s \pm \mu)\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} + s\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix}\right\} + b\frac{dy}{dt}\left\{+\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix} + \begin{vmatrix} a+d+f & f \\ f & b+c+f \end{vmatrix}\right\}$$

$$- \lambda\frac{dz}{dt}\begin{vmatrix} a+d+f & f \\ f & b+c+f \end{vmatrix}$$

$$\Delta z = A + B\frac{dx}{dt} + C\frac{dy}{dt} - D\frac{dy}{dt} - E\frac{dz}{dt}$$ multiplying by dt and integrating between $t=T$, $t=0$

$$\Delta z\int_0^T dt = A\int_0^T dt + B\int_0^x dx + C\int_0^y dy - D\int_0^y dy - E\int_0^z dz$$

Here the left hand term integral is adjusted to zero.

A is identically 0

the B term integral is x the final current in a and d

" C " " " y " " " " b " c

" D " " " q " " " charge in condenser K = by K

" E " " " 0 " " " "

so that $0 = Bx + Cy - D$ by k but $y = \frac{ax}{b}$

$$0 = Bbx + aCx - Dabxk$$

$$\therefore \quad Bb + aC = Dabk.$$

$$\therefore b\left\{-(l \pm \mu + s)\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} + (s \pm \mu)\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix}\right\} + a\left\{-(s \pm \mu)\begin{vmatrix} f & b+c+f \\ a & -b \end{vmatrix} + s\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix}\right\}$$

$$= ab^2k\left\{\begin{vmatrix} a+d+f & f \\ a & -b \end{vmatrix} + \begin{vmatrix} a+d+f & -f \\ f & b+c+f \end{vmatrix}\right\}$$

Determinants marked (1) and (2) are equal. Expanding and simplifying

$$\pm\mu(a+b) + lb = abck$$

whence $\mu = \pm\frac{n}{n+1}(bdk + l)$

$$n = \frac{lb}{\mu}$$

continued from page 30.

The total no. of lines of force ϕ in each segment should thus be $\frac{4800}{0.0213} = 1{,}36{,}600$ which represent an induction $\mathfrak{B}$ in the core of $\frac{1{,}36{,}600}{20} = 6850$ . . . . . armature . $\frac{6{,}36{,}600}{13} = 5700$

The external face of one segment of the armature being 24460 sq. cms × 13.0 = 320 sq. cms., makes an average induction of $\frac{4{,}36{,}600}{320} = 1360 = 13.6$ gauss.

The winding consists of 1 block # 18 B+S in the coarse wire 0.040"
5 - # 24 B.W.G. . . fine - 0.022".

There are 120 blocks in the coarse wire set = 20 blocks per segment
- . 240 - - fine - - = 40 . - -

In each coarse wire block there are two parallel wires 3 turns round = 3 effective turns, and there are 40 of these dits. per sector = 120 effective turns
In each fine wire block there is one wire 27 turns round (9 layers of 3 turns) and there are forty such dits. in a sector = 1080 effective turns.
The mean length of each turn effectively running is about 13 so that the mean coarse wire length = 1560 cms
" " fine " " = 14040 cms

The speed at which the machine runs in action is somewhat uncertain but the best estimate taken from repeating gear is 1600 revs. per min = 26.7 revs. per sec at 4.7 π = 394.0 cms per sec (10.3 ft per sec)
The volts in the fine wire set at full speed were 113 in coarse set
92.5 - fine.

From the coarse voltage the average field $= \frac{1.13 \times 10^{10}}{1.56 \times 3.94 \times 10^{6}} = \frac{1.13 \times 10^{4}}{6.145} = 18.4$ Gauss

- - fine - - - - = $\frac{9.25 \times 10^{11}}{1.404 \times 3.94 \times 10^{7}} = \frac{9.25 \times 10^{3}}{5.53} = 16.73$ -

. mean field = 35.13/2 = 17.6 Gauss

With this result we can approximate more closely to the reluctance of the cast iron for the total no. of lines $= 1.673 \times 10^{3} \times 3.20 \times 10^{2} = 5.35 \times 10^{5}$ allowing 10% for leakage = 5.88×10^{5} in the circuit ∴

$R = \left(\frac{5.88 \times 10^{5}}{9.3 \times 10^{3}}\right)^{-1} = 0.0159$ of this the air was taken 6 bc 0.0189 showing that there is an excessive error in the air space res. or a defect in the exciting power calculation.

Problem. Required the determination of dimensions arrangement and parts of a Continuous Current transformer operating between 1000 and 20 volts pressure, the H.P. delivered to be 20. = 15000 watts.

First for simplicity we will take two gramme armatures running side by side in the same field, and four poles. the peripheral velocity not to exceed 600 ft per sec. 2000 cms. per sec. For 15 kilowatts delivered, at 20 volts M.T. = 750 amperes.
In the experimental transformer the power delivered was 5 kilowatts. and the diam. of the ring was 18", for 15 kilowatts we may take the ring to be say 30" = 76 cms.
Maintaining the same proportion of the interior diam of the ring = 25" = 63.5 cms and the thickness of the ring = 2.5" = 6.35 cms
Since however this becomes a very large machine, it will be better to reduce the output slightly and make the exterior of the ring $\frac{4}{3} \times 18" = 24"$ (61 cms) external diam and $\frac{4}{3} \times 15 = 20"$ (50.8 cms) internal diam, and simply make the output with those dimensions as great as possible
The velocity with a diam. of 75.4" or 191.6 cms = 10.414 revs per sec = 626.4 per

Inductance Measurements

August 26th Monday).

Measurement made with induction coil having core of iron wire.

Diam: of rubber flanges 10 cms. of coil proper 9.2. length 6.3 cms (between flanges 5.2 cms) Diam of iron core about 1.6 cms. Short leads

No. of obs.	Ratio	Temp. B.	Res: obs.	Capacity	KBD	Kilometer	Difference	Mutual Inductance	Kilometer	
1	1000/100	25.5°	6.085	1.455	0.08854	885.4				
2	1000/100		73.03	14.565	0.3331	3336				
3	"		71.77	2.80	0.2010	2010	1326	0.12205	12205	

Similar measurements with a small phosphor box of fine coils

No. of Obs.	Bridge Ratio	Temp B	Res: obs	Capacity	KBD Secohms	Kilometer	Total all non cores Res:	Res: Diff.	KBD Secohms	Kilometer
1	1000/100	25.5°	0.248	0.30	0.00007424	0.7424				
2	1000/100		0.2431	0.275	0.00007328	0.7328	1.257	0.294	0.00036695	3.695
3			0.2426	0.275	0.00007326	0.673	sum = 1.3025			Sum 3.722
4			0.2775	0.287	0.00007964	0.796	Leads = 0.078			
5			0.2737	0.287	0.00007852	0.785	L to be deducted			
					0.7322					

3rd Ann. induction coil, braided length 23.6 cms, diam 3.4, iron wire core 1.3 diam

No. of obs	Bridge Ratio	Temp B	Res: obs	Capacity	KBD	Secohms	Kilometer	Difference	Mutual Inductance	Kilometer
1	1000/100		0.056	2.100	98.95	0.00988	98.98			
2	1000/100		139.36	4.265	574.200	0.57442	5742			
3	"		139.34	2.515	489.800	0.4898	4898	1044	0.0449	449
4	"		139.35	5.000	696.750	0.69675	6967.5	1025.5	0.0932	932 } 900

4th Train communication system low induction coil.

No. of obs.	Bridge Ratio	T. B	Res: obs	Permittance	KBD	Secohms	Kilometer	Difference	Mutual Secohms	Kilometer
1	1000/100		700.9	1.408	987×10^{-6}	0.0987	98.70			
2	1000/100		3.952	0.745	2.969×10^{-6}	0.0003	29.67			
3	" "		3.952	4.690	18.67×10^{-6}	0.0187	186.7	157.03	0.0155	155.5
4	1000/100		705.0	1.095	772×10^{-6}	0.772	7720	2150	0.0195	195.4

5th Station induction coil.

No. obs.	Bridge Ratio	T.B.	Res: obs	Permittance	KBD	Secohms	Kilometer	Diff.	Mutual Secohms	Inds: Kilometer
1	1000/100		30.866	0.633	19.54×10^{-6}	0.1954	1954			
2	"		30.866	alt o Cell Res	0	0	0	2000 alt		1960?
3	"		31.72	0.638	19.38×10^{-6}	0.1938	1938			
4	"		31.72	1.335	42.35	0.42.35	4235	2297	0.2274	2274

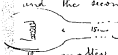
6½ Single coil braided and with iron wire core. length 8.2 diam 6.3
7th - - - papered 4.0 3.5

No. of obs.	Bridge Ratio	Res: obs	Permittance	KBD	Inductance Secohms	Inductance Kilometer	Leads	Res. @ 20°C	Time Constant
1 th	1000/100	6.990	0.557	3.593	0.0359	389	0.07	6.92	0.00582
2 th	T.B. 25°C	7.716	2.031	15.670	0.1567	1567		7.646	0.0205

Electrical Radiance Experiment.

August 27th Tuesday.

Tried to ascertain whether with the aid of ultraviolet rays, any distinct sparking distance could be detected with 100 volts pressure. Arranged the sparks micrometer with its points in close proximity, and illuminated them with a lamp having a quartz window on the plan described and illustrated in the preceding record book page 104. The two such lamps were used the first of 50 c.p. and the second of 16 c.p. spiral carbon and the tube projected 15 mm from the head of the bulb as shown.



No results were obtained with 100 volts although the medium is by no means definitely decided. With 110 + 135 = 245 volts however some rough results were obtained indicating that there is a definite (but scarcely visible) sparking distance for that pressure and that it is assisted by ultraviolet rays. No more than this could be determined before the two lamps had been successively destroyed by over pressure.

Phonograph Potash Battery Test

Observer K Lehmann.

Compared two phonograph potash cells in series, with one Leclanché cell by working them alternately five mins: at a time through 20 platinoid wire, a clock changing the contacts automatically.

Particulars KHO cells.

Glass cell 8 diam (out). Total height 15 cms

Cu Peroxide plate length 12 Breadth 4·5 Thickness 0·8

Zinc rod. " 11 diam. 2·0

Leclanché cell

Glass cell height 15·5 Diam 12

Zinc rod length 16·7 " 0·9

Carbon prism pot " 12·8 " 8

Carbon " Breadth 4·6 Thickness 1·2

Weight of zincs in KHO cells before start (after amalgamating) and drying No 1 239.64 No. 244.2.55

Test commenced 16th Aug. 10 o'clock. continued uninterrupted till 22nd Aug. 8 o'clock 192 hours, by which ~~both~~ both KHO cells exhausted.

The Leclanché cell was practically exhausted after 10 hours.

The weight of the KHO zincs after drying was No 1/179·8 No 2/179·9

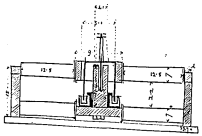
Total loss. 123·49 grammes.

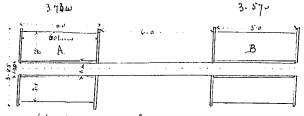
Total calculated output in coulombs from curve sheet in book = 364700 which represents 423.57 grammes so that the observed and calculated zinc consumption practically coincide.

The solution of KHO was of sp. g. 1·20 (NaHO strength)

The sounder contacts were reversed every 12 hours to make sure that the test was fair. That is to say the ~~by~~ contact battery was made the bottom contact battery and vice versa.

Made a rough measurement of the amount of current necessary to practically operate a motor of drum type shown on the opposite page. With 11 ampères through the armature and about 3 amp through the fields in parallel = 0.75 through each magnet the torque was roughly 3 grammes weight at periphery, friction rendering it very difficult to measure more accurately so that if the strength of average field = $\frac{p}{2l}$ = $\frac{3 \times 980 \times 4 \times 33}{1.1 \times 9.5}$ 667 = 6.67 gauss





18 layers × 80 turns = 660 turns on each.
Mean diam = $\frac{3.85+1.80}{2}$, 4.55, 2.28 cms
= 1.434 π cms of wire on each spool. 145 gr. 1.720 cms
wire 1.33 B.W.G. 0.035" = 0.083 cms
150 gr of this wire has resist of 2.64Ω

Inductance Measurements.

Aug. 28th Wednesday.

Measurement of double coil.

No. of Obs.	Bridge Ratio	Res. Std.	Balpy	K.B.D.	Inductance Seckms	Kilometres	Difference	Mutual Seckms	Inductance Kilometres	Mean	Mutual Ind. Kilometres
1	10000/100	3.7444 A	0.927	3.471	0.0347	347.1					
2	TB 213.5 C	3.583 B	0.971	3.48	0.0348	348.					
3	B A_{11}	3.587	0.794	2.849			0.631	0.006246	62.46		
4	B A_{21}	3.587	1.172	4.204			0.724	0.007168	71.68	67.07	
5	A B_{12}	3.664	0.777	2.847			0.624	0.006178	61.78	66.3	
6	A B_{22}	3.664	1.141	4.180			0.700	0.006930	69.30	65.54	

Further measurements were then taken to find the influence of magnetic stress on the core upon the inductance.

1st When B coil tested for inductance. A open. Balpy for balance 0.967
A short circuited by wire . . 0.955

This clear difference of about 1.3% less inductance in B, when the A coil short circuited is perhaps due to the reaction on the core of induced currents in A following those in B by $\frac{\pi}{2}$.

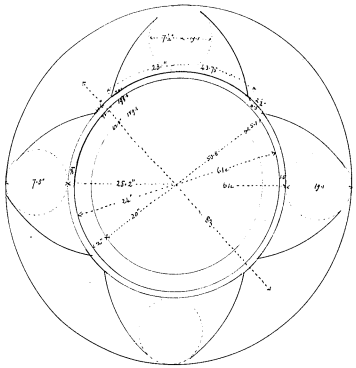
2nd When B coil tested and A magnetized by dynamo current.
The magnetizing current was approximately $\frac{110}{270}$; $\frac{110}{60}$ or 0.407 + 1.83 amp

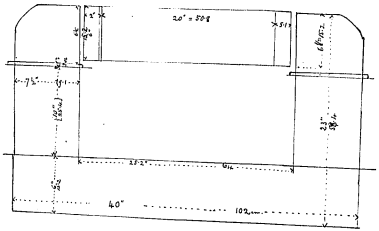
No. of Obs.	Bridge Ratio	Res. Std	Balpy	K.B.D	B Inductance Seckms	Kilometres	A coil	Res. in coil with 110 volts	Current in A	% Red. in Inductance
1	10000/100	3.6030	0.953	3.43	0.0343	34.3	open	∞	amperes.	
2			0.958	3.451	0.0345	34.5	open but touching	270	0.407	
3			0.952	3.430	0.0343	34.3	open	∞		
4			0.832	2.998	0.0300	30.0	closed	60	+ 1.83	12.75%
5			0.936	3.373	0.0337	33.7	open	∞		
6			0.840	3.026	0.0303	30.3	closed (reversed)	60	−1.83	12.18%
7			0.940	3.387	0.0339	33.9	open	∞		

To examine this effect more closely repeated the measurements with the 1st coil between the pole of the large electro magnet in such a way that the iron wire core joined them across. Fig.

No. of Obs.	Bridge Ratio	Res. std. including leads	Balpy	K.B.D	Inductance Seckms	Kilometres	Condition	Current in coil with mag. amperes	Lamps in box
1	10000/100	9.2720	0.426	3.950	0.0395	395.	free in air		
		9.262	1.217	11.270	0.1127	1127	between pole	0	0
		——	.336	3.112	0.0311	311.	"		1
		"	.190	1.760	0.0176	176	"		2
	9.233		.134	1.237	0.0124	124	"		3
		——	.115	1.062	0.0106	106	"		4
		——	.108	0.997	0.00997	997	"		7
		——	.105	0.969	0.00969	96.9	"		8
		——	.095	0.8772	0.00877	87.7	free in air (low mag.)	20	60
							free in air (low mag.)	0	

From this it would appear that the inductance of a coil whose iron core is nearly saturated with magnetism is only 10% greater than when that core is entirely removed. In this instance the inductance was 4.5 times as great with the core in air as without it





With the dimensions shewn, the length of one sector is 147·9 cms external on arc, or 148 cm practically.

The magnetic path is made up as follows.

In each limb mean length 27·9 mean area $\frac{286.5}{2}$ $\quad \frac{L}{A} = \frac{27.9}{143.3} = 0.195$

The conductancy may be estimated at 500

In the base the mean length is 60 cms. and the area 290. So that $\quad \frac{L}{A} = \frac{60}{290} = 0.207$

In the armature the mean length is 22 cms and the area 91 sq. cms. $\quad \frac{L}{A} = \frac{22}{91} = 0.242$

In the poles the mean length is abt 15 cms and the area 200 sq. cms. $\quad \frac{L}{A} = \frac{15}{200} = 0.075$

In the air the mean distance is 1·5 cms. and the area 22 sq. cms × 15·2 = 334 sq cms $\quad \frac{L}{A} = \frac{1.5}{334} = 0.00449$

The total reluctances may thus be taken as

$$2(0.00449) + \frac{2(0.075) + 2(0.195) + 0.207}{500} + \frac{0.242}{700}$$

$$0.00898 + \frac{0.150 + 0.390 + 0.207}{500} + \frac{0.242}{700}$$

$$0.00898 + \frac{0.747}{500} + \frac{0.242}{700} = 0.009 + 0.00015 + 0.00035$$

$$= 0.0109$$

The field winding is determined by the heat of the field. It is proposed to charge the magnets from the secondary circuit and the surface of each coil will be about 29 π × 25 = 1806 sq cms allowing 20 sq. cms per Watt = 90 Watts per magnet, limit and at 20 volts = 4·5 amperes, and the res. will thus be 4·44 ω

The coiling space may be taken as 3/16" = 1·9 cm. so that it becomes

$$\cancel{\frac{\pi}{4}(29.0^2 - 4.44\pi)} \quad \frac{\pi}{4}(22.9^2 - 19.1^2) = 125.3 \text{ sq cms} \times 25 = 3130 \text{ c.c.}$$

$$d = -\frac{L}{2} + \sqrt{\left\{\frac{L^2}{4} + 0.00153\sqrt{\frac{3130}{4.44}}\right\}} = -0.008 + \sqrt{(0.0002 + 0.0153 \times 26.5)}$$

$$+ \sqrt{0.0002 + 0.405}$$

$$= -0.008 + \sqrt{.40855}$$

$$= -0.008 + 0.2014$$

$$= -0.1934 \text{ cm.} = 0.076" = \#15 \text{ B.W.G.}$$

This wire has 502 ft per ω + weighs 7.88 lbs per ω = 2230. in all - 35 lbs. for all per magnet

When covered, this wire will have a diameter of 0.072 + 0.008 = 0.080" = #13 so that there will be 125 turns to the layer, and in 1·9 cms there will be 9·36 layers, say 9 = 1125 turns in all the mean turn having a diam: of 21 cms = 66 cms circ: = 7 ft. 2·40 cms = 1860 feet = 3·7 ω with 10 layers = 1250 turns = 82500 " = 2070 " = 4·44 = 32·5 lbs and the number of ampere turns on each sector = 1250 × 4·5 = 5625

" " " " " " " pair of turns = 11250

" " exciting power for each pair 4π nc = 14,140

so that the total number of lines $\varphi = \frac{14,140}{0.0109} = 1297,000$

the induction $\mathfrak{B}$ in the cores is $\frac{1,300,000}{45.45 \times 2} = 14$ Gauss.

of this 1300,000 we may assume 10% 286 to be lost by leakage leaving 1170,000 available. The whole surface of one sector of the ring at the periphery is 50 × 15·2 = 760 sq. cms, so that the average field = $\frac{1170,000}{760}$ = 1540 or 15Ω Gauss

The peripheral velocity being 2000 cms per sec., and the length of one turn 155 cms we have $n = 1000 \times 10^8 + (2.0 \times 1.55 \times 1.5 \times 10^7) = 10 \times 10^8 + 4.65 \times 10^7 = 14.65 \times 10^7$

$= 20 \times 10^8 + (1.5 \times 1.55 \times 1.5 \times 10^7) = 20 \times 10^8 + 4.65 \times 10^7 = 24.65 \times 10^7$

So that the turns per sector must be $\frac{1465}{2210}$ + $\frac{50}{1434}$ respectively

= 2·25 + 1·15 say.

To integrate the last term $\frac{t}{r}\int_0^{2\pi}\frac{d\theta}{(a+b\cos\theta)^{\frac{1}{2}}}$

Let $= \frac{d\theta}{(a+b\cos\theta)^{\frac{1}{2}}} = \frac{d\theta}{\left\{(a+b)\cos^2\frac{\theta}{2}+(a-b)\sin^2\frac{\theta}{2}\right\}^{\frac{1}{2}}}$

$= \frac{\cos^2\frac{\theta}{2}\,d\theta}{\left\{(a+b)+(a-b)\tan^2\frac{\theta}{2}\right\}^{\frac{1}{2}}} = \frac{\sec^2\frac{\theta}{2}\,d\theta}{\left\{(a+b)+(a-b)\tan^2\frac{\theta}{2}\right\}^{\frac{1}{2}}}$

Let $\tan\frac{\theta}{2} = z$

$\frac{1}{2}\sec^2\frac{\theta}{2}\,d\theta = dz$

$\sec^2\frac{\theta}{2} = 2dz/1+z^2$

$\sec\frac{\theta}{2} = \sqrt{1+z^2}$

$\sec^2\frac{\theta}{2} = (1+z^2)^{\frac{1}{2}}$ $\quad d\theta = \frac{2dz}{1+z^2}$

$= \frac{(1+z^2)^{\frac{1}{2}}\times\frac{2dz}{1+z^2}}{\left\{(a+b)+(a-b)z^2\right\}^{\frac{1}{2}}} = \frac{2(1+z^2)^{\frac{1}{2}}\,dz}{\left\{(a-b)(1+z^2)+2b\right\}^{\frac{1}{2}}} = \frac{2(1+z^2)^{\frac{1}{2}}\,dz}{\left\{(1+z^2)(a-b)+2b\right\}^{\frac{1}{2}}} = \frac{2dz}{(1+z^2)\sqrt{a+b+\frac{2b}{z^2}}}$

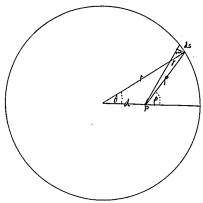
Let $(1+z^2)^{\frac{1}{2}} = y$ $\quad$ Then $\frac{2z}{2y}dz = dy$ $\quad z^2 = y^2-1$ $\quad z = \sqrt{y^2-1}$

$\therefore\ dz = \frac{y\,dy}{y^2-1}$

Let $1+z^2 = y$ $\quad$ Then $2z\,dz = dy$ $\quad dz = \frac{dy}{2z}$

Problem.

The magnetic field produced by an annular current of strength c and radius r at the center is $\frac{2\pi c}{r}$. Required the strength of the field at any point P^r distant d from the center, but within the ring.



$df = \frac{ds\cos\gamma}{\rho^2}$

$\sin\gamma = \frac{d}{\rho}\sin\theta$

$\cos\gamma = \sqrt{\rho^2-d^2\sin^2\theta}$

$\rho^2 = d^2+r^2-2dr\cos\theta$

$ds = r\,d\theta$

Also let $d = pr$

Then $df = \frac{r\,d\theta\sqrt{d^2+r^2-2dr\cos\theta-d^2\sin^2\theta}}{(d^2+r^2-2dr\cos\theta)^{\frac{1}{2}}}$

$= \frac{r^2d\theta\sqrt{p^2+1-2p\cos\theta-p^2\sin^2\theta}}{r^3(p^2+1-2p\cos\theta)^{\frac{1}{2}}}$

$= \frac{d\theta}{r}\frac{(1-p\cos\theta)}{(1-p\cos\theta+p^2)^{\frac{1}{2}}}$

$\therefore\ F = \int df = \int_0^{2\pi}\frac{d\theta}{r}\frac{(1-p\cos\theta)}{(1+p^2-2p\cos\theta)^{\frac{1}{2}}} = \frac{1}{r}\int_0^{2\pi}\frac{k+q\cos\theta}{(a+b\cos\theta)^{\frac{1}{2}}}$ $\quad \left(\begin{array}{l}k=1\\ q=-p\\ a=1+p^2\\ b=-2p\end{array}\right)$

Let $q = sb$ and $k = sa+t$ $\therefore s = \frac{1}{2}$ & $t = \frac{1-p^2}{2}$

Then $F = \frac{1}{r}\int_0^{2\pi}\frac{(sa+sb\cos\theta+t)\,d\theta}{(a+b\cos\theta)(a+b\cos\theta)^{\frac{1}{2}}} = \frac{s}{r}\int_0^{2\pi}\frac{d\theta}{(a+b\cos\theta)^{\frac{1}{2}}} + \frac{t}{r}\int_0^{2\pi}\frac{d\theta}{(a+b\cos\theta)^{\frac{1}{2}}}$

$\qquad\qquad\qquad

Particulars of Machine

No. of Poles	4	
Pole surface	237 x 15"	1422
Diam. Core	73"	1.85
Length "	10"	25.4
Exp. diam. inside excitation	40"	1.13
Armature		
Bot. diam.	26.0"	66
Slot	20"	50.8
Thickness	2"	5.08
Depth	6"	15.2
Gap face	0.75"	1.9
Gap corner	0.75"	0.62
Periphery of iron	75.4"	191.6
" wound on	78.9	130.1
Designed rel. revs per min	626.5	
Peripheral speed fpm for 626 revs	2000.7	
" " " 960 revs	1530	
Velocity revs per sec	10.44	
Peripheral length of outer	19.65"	49.8
" " inner	17.55"	44.6
Inside length " "	15.7"	40
" " core	10.5	27
Calculated magnetic Induction in air gap	9100	
" " core	6550	
Ampere turns in air gap	1.0	
Magnetic flux per pole	2,400,000	
" leakage	1,200,000	
" flux leak to adjacent poles	1,200,000	
" " "	1,200,000	
" " "	1,200,000	
" " "

Solar Observations for Time

2nd September 1889.

Clock Time 9. 07. 00
4. 56. 54
Approx G.M.T. 2. 10
Mag. Decl. 8°.15'.

9. 07. 00
9. 58. 48
Clock error + 8. 12

Hour angle by transit 45°. 24'. 30" = h 3 . m 1 . s 38
a.T. = 8 . 58 . 23

Equation of time @ G.noon = 32.4 s.
Correction for 2 hour 1.6
Equation of time @ obs. 34.0.

M.T. of obs. 8 . 57 . 48
Long. W. of N.Y. 1 . 00
N.Y. M.T. 8 . 58 . 48

2nd trial Mag. Decl. 8°.15'
Clock Time 9. 27. 00
Long 4. 56. 54
Approx G.M.T 2. 24.''

Clock time 9. 27. 00
Calculated 9. 18. 08
Clock error + 9. 00

Hour angle by transit 40°. (less semidiam) 29. 20'
a.T.

Equation of time

2 . 41 . 56
9 . 18 . 04
. 34

M.T. of obs. 9 . 17 . 30
Long. W. of N.Y. 1 . 00
9 . 18 . 30

Sept. 2nd Monday

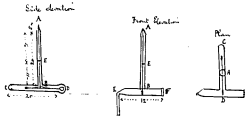
Electrical Radiance.

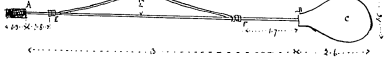
Repeated experiment mentioned on page 35 using pressure of about 170 volts on the lamp, and 200 volts through water resistance tubes on the spark micrometer, but unable to obtain any results at that pressure.

Changed the experimental direction. Took a delicate suspension in glass tubes represented on the opposite page. The intention has been to exhaust this apparatus but owing to leakage round the quartz window, this has not yet been successfully accomplished. It therefore contained air at external pressure

AB. CD & EF are 3 glass tubes at right angle AB being vertical and having sealed into its upper extremity a fine platinum wire 0.002" thick with a small directing steel magnet E 3 cms long + 0.25 broad 0.1 thick, passing through a hole in its centre and then sustains beneath an aluminium suspension of wire with a steel counterpoise at one end and an aluminium vane in the other of dimensions shown.

AB is 35 cms long 2.5 diam ext. BD 23 cms long 2.5 in diam. and EF is 12 cms long + 2.5 diam. EF has an exhaust tube at one end and a quartz window at the other.





The suspension swinging freely and under control of a directing magnet about the level of E, the window was placed opposite to the window of the spiral carbon lamp so that the latter could directly illuminate one face of the vane which was neither polished nor dulled. On examining the position of the vane with a telescope some 3 metres distant it was observed that a slight and slow motion of repulsion took place when the lamp was brought to vivid illumination. That is to say the vane very slightly and slowly retreated. A strip of clear glass inserted between the windows and placed in the path of the beam did not seem to exercise any great effect and two or three plates of ochre and red did not seem to greatly reduce the effect although screens were placed between lamp and apparatus to cut off all extraneous heat influence. A blue glass plate however appeared to extinguish the influence pretty effectually. A water chamber of good construction with clear glass sides and enclosing a liquid vertical station nearly 1 cm thick appeared to entirely cut off the influence although the vessel itself unfilled did not do so. The interposition of a Nichol prism seemed to cut off the influence.

Particulars of Machine

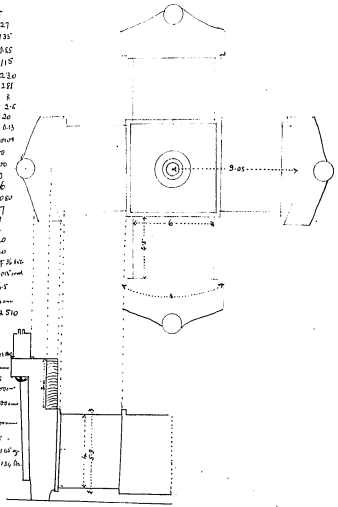
Poles 4

Weight of field 2316 lbs 10500
- armature 474 2115
- (wound)

Layers on limbs 5
Turns per layer 27
Total turns 135
Ampere in field 0.85
Ampere turns 115
A.T. per pair 230
Exciting power 281
Length of pole face 8
Depth 2.5
Area 20
Mean air space 0.13
Mean reluctance 0.0108
Mean flux = 26,700
Mean flux the air 18700
Average field 510
Area of face 36.6
Turns on armature 1080
- per block 27
- layer 9
Layers per block 3
Commutator bars 40
Blocks in armature 40
Size of wire in armature #16 B.W.G.
Diameter 0.054" insulated
Circumference armature 18.5
1 turn per sec = 0.9 cm
Calculated mean field 510
Res. of armature 0.25 Ω
- - field 1.92 Ω
Size of wire in field #19
Diameter 0.042" insulated
Length of field wire 16
field per limb = 3200 cm
Total field wire 420 ft 12,800 cm

Armature wire
27 feet weigh 2.4 grammes
1 - 0.089 -
- 0.002150 g
- 0.000136 lb

Plan of Magnet ½ size



(41)

Data Concerning the Phonograph Motor.

Sept. 3rd 1889.

Two machines were compared similar in all apparent respects except that one had a cast iron armature while that of the other was composed of wrought iron plates.

The test was made with one Chromic acid cell having an emf of 1.916 volts.

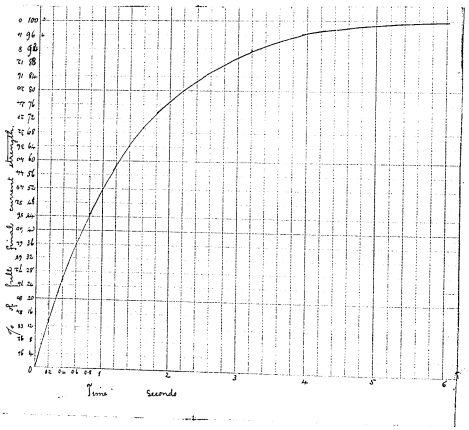
Wrought iron armature (2) and cast iron armature (1) No. Phonograph cylinder

Machine	Condition	Clock sec.	Current in amperes	PD on terminals	Watts	Speed revs. per min	Revs. per sec.	Equivalent revs.	Actual revs.	Commutator corr. factor	Load
Wrought iron armature (2)	Running free	0.573	2.929	1.572	4.62	365	6.08	0.535 w			
	Held	1.120	5.74	1.296	7.44	0	0	0.226 w			
	Armature at Field	0.430	2.205	1.584	3.49	365	6.08	0.718			
		0.980	5.03	1.296	6.52	0	0	0.258	0.255		1.022 watts
	Field cut	0.16	0.82	1.572	1.29	365	6.08	1.92	1.92		Power wasted absorbed at this speed 2.235 watts.
	Held	0.11	0.564	1.296	7.31	0	0	2.20			
	Governing	0.63	3.23	1.576	4.86	216	3.6	0.466			0.488 Eff. @ 365 revs.
		1.12	5.75	1.296	7.45	0	0	0.226			Volt for revs. per min 0.00240
Cast iron armature (1)	Running free	0.365	1.87	1.720	3.22	440	7.33	0.920 w			
	Held	1.08	5.54	1.286	7.12	0	0	0.232 w			
	Armature at Field	0.180	0.92	1.720	1.58	440	7.33	0.87 w			1.425 watts
		1.00	5.13	1.286	6.60	0	0	0.254 w	0.255		Power wasted absorbed at this speed 0.00337
	Field cut	0.180	0.92	1.720	1.58	440	7.33	1.87	1.92		1.366 watts
	Held	0.130	0.667	1.286	0.857	0	0	1.93			
	Governing	0.43	2.205	1.656	3.65	212	3.53	0.75			0.865 Eff. @ 440 revs.
		1.08	5.54	1.286	7.18	0	0	0.232			Volt for revs. per min 0.00337

There are on each limb of the field 5 layers of 27 turns = 135 turns making 105 feet or 3200 cms. of #19 B.W.G. 0.042" diam. The current in the field cut averages about 0.85 amp = 115 ampere turns = exciting power of 1444 on each limb. The polar faces are of 20 sq cm area and the average air space is about 0.13 so that the total reluctance = $\frac{0.26}{20}$ = 0.0108 and a pair of limbs giving 288 magnetic lines gives 26700 lines and the area of one gradient face of the armature is 36.6 sq cms giving an average armature field of 730 or 7.3 gauss. In the armature there are 40 blocks of 10 per sector each having 3 layers of 9 turns = 27 × 10 or 270 turns per sector = 702 linear active wire. One turn per sec = 5.65 cms per sec. peripheral velocity. one turn per min = 0.094 cms per sec. ∴ 702 × 10² × 0.094 × 7.3 × 10⁻⁸ ÷ 10⁸ = volts per rev. per min = 4.52 × 10⁻⁸ = 0.00452 by calculation, everything depending however upon the estimation of the air space, so that the test field = 0.26 gauss for wrought iron and 4.26 gauss for cast iron.

The torque was 0.85 × 1000 grammes = 850 cm gms when 7.1 amperes flow through the armature and 7.1 × 10¹⁰ × 7.0 × 10⁷ × 0.5 × 10³ × 9.0 = 1.64 × 10¹⁰ × 7.0 × 10⁷ the first torque being 8.50 × 10⁵ against 11.6 × 10⁷

Weight of armature 2125 gms wound.
- field 10200 -



Measurement of Inductance of Ore Milling Radial Magnet.

Three of the four quadrants each of 5 magnets in the large radial ore milling machine were tested for their approximate inductance as follows:—

The current passing through the magnet was measured and the discharge received on the ballistic galvanometer with a closed set discharge key. This discharge was compared with that from a condenser.

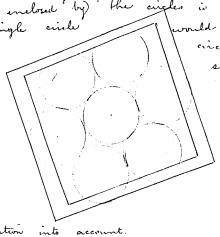
No. of Magnet	Shown 10ω	Current thru magnet amperes	Disch.	Mean C.	Mean Disch	Res. in Galvos.	Q	$\frac{QR}{\pi} = L$	$\frac{L}{R}$	Mean Inductance	Mean $\frac{L}{R}$
								seconds			
1	0.466	0.0932	118				$\frac{120}{123} \times 1.426 \times 10^{-10}$		R = 6.44		
	0.466	0.0932	129								
	0.466	0.0932	127	0.0957	130	55300	1.507×10^{-10}	8.71	1.42		
	0.492	0.0984	134	$= 9.57 \times 10^{-3}$ dec mea		$5.53 \times 10^{4} \times 10^{3}$ 5.53×10^{10}					
	0.492	0.0984	136								
	0.489	0.0978	133								
2	0.494	0.0988	190								
	0.496	0.0912	202								
	0.496	0.0912	190	0.0932	147	55300	$\frac{1.426}{147} \times 147^{10}$	7.66	1.28	8.243	1.38
	0.476	0.0952	96				1.704×10^{-10}				
	0.500	0.100	102								
	0.500	0.100	103								
3	0.507	0.1076	123								
	0.498	0.0996	126								
	0.490	0.0980	128	0.0997	130	55300	$\frac{1.426}{123} \times 130^{10}$ 1.507×10^{-10}	8.358	1.36		
	0.502	0.1004	138								
	0.497	0.0994	135								
	0.496	0.0992	132								
Shunt	EMF C.C.	Charge Measured	Charge abs. mea	Deflection	Res. of Galvos						
Condenser	1.426	1.426	1.426×10^{-10}	123	5290						

At 110 volts the current is 18 ampere = 1980 Watts and the electrokinetic energy in one quadrantal set of magnets is thus $\frac{1.37 \times 1980}{2}$ = $\frac{2720}{2}$ Joules $\frac{27200}{2}$ Megalergs = $\frac{6148}{2}$ therms.

The condition for the aggregation of a perfect strand of the 2nd order is that n=1 centers may form a polygon each vertex of which shall be at 4r from the axis. This polygon is evidently the hexagon formed by the aggregation to one common vertex of six equilateral triangles of side 2r, so that the shortest distance or apothem is $\frac{\sqrt{3}}{2} = \frac{1.73}{2} = 0.865$, a reduction of 13%.

The circumscribing hexagon square perpendicular to the major diameter has a length of side = 6r and an area = $36r^2$.

The area enclosed by the circles is $7\pi r^2 = 21.9912\, r^2$ the equivalent single circle would have a rad. of $\sqrt{7}\, r$ and the circumscribing square would have a side of $2\sqrt{7}\, r$ and an area of $28r^2$, consequently for armature winding purposes neglecting insulation there is a saving of 22%.



Taking insulation into account.

Let the insulation thickness be t. Then the side of the square on the strand is $6(r+t)$ the area $36(r^2+2rt)$. The side of the square on the single wire $2(\sqrt{7}\, r + 2t)$ and the area $28r^2 + 8\sqrt{7}\, rt$.

The difference is $8r^2 + 2\sqrt{15}\, rt$ and with $r = 0.15$ and $t = 0.012$

this is $8 \times 0.0225 + 0.0018 \times 2.15$

$0.20 + 0.038807$

$= 0.2381$

$36r^2 + 72rt = 36\,(0.0225 + 0.0018t)$

$= 36\,(0.02463)$

$= 0.87468$

a reduction of 27%.

Measurement of the Obach Ring Constant

(43)

Observer Lehmann

Sept. 3rd 1889.

A dynamo current was passed through the ring of the Obach and a silver voltameter in series for 300 seconds. The observed deflections made a mean of 0.390 on the tan. scale.

The weight of the silver plate was before	18.4287	anode	15.5130
after	17.7619	cathode	16.1669
	0.6668 loss		0.6539 gain.

Taking the loss = 0.6668

= 596.3 coulombs

= 1988 ampères

= 0.196 on the tangent scale per ampère.

Problem

Required the winding and electromagnetic measurement of a car motor to deliver 7 H.P. (5250 Watts) at full load from a source of 20 volts, the counter emf to be 10 volts and the nominal efficiency 90%. The motor to be of the Gramme ring type with two opposed field magnets like the Fuller Gramme. The yoke to be of cast iron and the pole pieces also, the limbs being of best wrought iron. The armature to have a trial diameter of 12" over all and to have a peripheral velocity of 1200 feet a minute.

In the #20 machine 6 wires each of 48,400 cm carry 400 ampères that is 290400 cm in all or 726 cm. per ampère.

In the #2 M machine 2 wires each of 9025 cm carry 30 ampères that is 18050 cm. in all or 600 cm. per ampère.

Since this motor will have considerable ventilation from free outdoor air we may take 500 cm per ampère. Then it has to receive 525 ampères $\times \frac{10}{9}$ = 525 + 58 or 583 ampères at full load and half of this will be on each side of the armature viz 290 ampères so that 145000 cm. is required. Equivalent to a #00 B.W.G. wire. As this wire cannot be worked it may be divided into a cable of 7 #9 B.W.G. wire each 0.148" diam. and of 21,900 cm each making 153300 cm. in all. Bound these wire would be 0.163" (0.414 cm) The theoretical winding space depth for the seven wires would be 1.15 cm. = 0.28" but practically it will be necessary to allow 0.49" (1.245 cm) in depth and breadth.

The diam. of the armature over all being 12" (29.5 cm) the diam. at the strand center will be 29.23 cm. a circumference of 91.85 cm. which divided by 1.2445 gives 73.8 say 70 turns = 35" on each side half of the ring. If the active breadth be taken at 6" (15.2 cm) the total active length per half ring = 5320 cm.

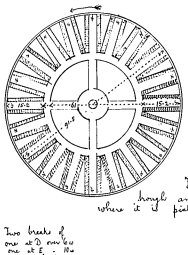
The speed at which this runs through the field is 36000 cm per min = 600 cm per sec. Calling the average field f, since the speed when running light must ~~be~~ provide 20 volts at M.T. we have

$$2.0 \times 10^3 = f \times 5.32 \times 10^2 \times 6.00 \times 10^2 = 31.92 \times 10^4 f$$

$$f = 6.265 \times 10^3 = 6270 = 62.7 \text{ Gauss.},$$

a far stronger field than we can expect to obtain commercially. With a peripheral speed of 1800 feet a min. the field would have to average 41.8 Gauss. at 125 volt the average field in a #20 armature is 32.5 Gauss.

For the field a ring of 18" diam. 14.5" at min center = 36.8 cm. = 115.6 cm. circumference = 92.82 say 93 turns 46 on each half. $46 \times 15.2 = 699.2 \times 10^2$ at 1200 ft per min $f = 46.8$ Gauss. at 1800 ft per min = 32.4 Gauss.



20 magnets each 30" (122 cms) × 5" (12·7) × 2" (5·1) wound with 51 lbs (1418 ft) (43240 cms) of # 12 B.W.G. 0·109" (0·442) diams. Each quadrant of 5 magnets in series, making 6·1 Ω coil. (20°) The exterior brass surface of the drum being 35100 sq. cms. the faces and 13300 on the two sides together a total of 48400. The energy is $3 \times 1/2 \times 110^2 = 56100$ ergs or 56 sq. cms. per Volt. The whole cylinder which is watertight revolves on the axis in a bath of water and emulsifies the ore. The ore is pulled on to the cylinder in the bath and brought up to the left hand top quadrant where it is picked off by a separate magnet.

1st plan. Two breaks of the extra current one at B one by one at E. The two must sparking

2nd plan. Two breaks the first through 6v the second a short circuit on the magnets. A diminished spark occurred at the first break and a bad one at the second, owing to dynamo current.

3rd plan. Same electrical connections but a pair of carbon rods made to flash the spark in the 6v cct after the break bridged the second break. Effectual in operating but very difficult to for exact adjustment.

4th plan. Solenoid in 6v cct. to open it at instant of bridging second break. Too slow.

5th plan. Same solenoid in short circuiting wire round magnet. Too fast.

6th plan a double strip for second break to rest upon. Two breaks as before. B on 3v C on 3v more A the short circuiting strip. D the carbon spark point mechanically operated by the passage of the brush round the 6v strip.

Inductance Measurements

September 6th 1889

Induction coil. Braided. Length 12 Interflange 10·7 Int. Diam 7.15 Ext. 1·7

Diam of wire wire cov 1·4.

No of Ratio	Bridge Ratio	Res. std. T.B. 35°C.	Pri. Coil	Sec. Coil	Condenser	K.B.D.	Inductance Sec. Ohms	Inductance Kilometer	Difference	Mutual Ohms	Inductance Kilometer
	10000/100	0·389	tested	disc.	1·195†	4·648 × 10⁻⁵	0·026648	46·48			
	10000/100	13073	disc	tested	0·675†	8826 × 10⁻⁵	88·26	88·2600			
	"	13075	in bath at	"	0·670†	8740 × 10⁻⁵		874000	0·66	0·60	6000
		"	" rest	"	0·680†		88·90	889000	0·64	0·582	5820
											5910 Mm

Induction coil of iron wire length 10.6 Interflange 9.85. Diam over last layer 3.6. Int. 2·9 No core. 4 layer of 200 turns each, layers separated by paper. Diam of wire 0·011" = 0·0279 covered 0·017" = 0·0143

No of Ratio	Bridge Ratio	Res. std.	Condenser	K.B.D.	Inductance Sec. Ohms	Inductance Kilometer					
	10000/100	412·12	0·003	1236	0·001236	12·36					
	100/100	412·25	0·048	1979	0·001979	19·79					

Induction coil of copper wire length 10.55 Interflange 9.9 3.6. Int. 2.8. No core. 4 layer. Diam wire 0·0375"

No of Ratio	Bridge Ratio	Res. std.	Condenser	K.B.D.	Inductance Sec. Ohms	Inductance Kilometer					
	10000/100	143·29	0·325	4·657	0·04657	4·657					

Radial Ore Milling Machine.

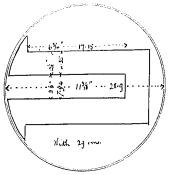
The connections for the radial ore milling machine are as shown on the opposite page. The time constant of five magnets in series is shown on page 42 to be 1·35 seconds. The spark at the commutator on breaking the field at the non-magnetic quadrant is violent. Two breaks across successively increasing resistances did not sufficiently reduce it. The full discharge at 18 amperes through its own resistance amounts to $18 \times 8{\cdot}24/4{\cdot}000 = 2{\cdot}22$ volts. e.m.f. equal to 125 volts charging 200000 microfarads. or 110 volts charging 22.440 †

The energy of the charge would be $\frac{EQ}{2} = \frac{E^2 S}{2}$

$$= \frac{(110 \times 10^8)^2 \times 2{\cdot}244 \times 10^6 \times 10^{-15}}{2} \text{ ergs}$$

$$= 1{\cdot}21 \times 10^{20} \times 1{\cdot}122 \times 10^{-11} = 1{\cdot}357 \times 10^{10} = 1357 \times 10^7 \text{ ergs} = 1357 \text{ Joule.}$$

The plan finally adopted for breaking the spark was to use one insulated bar and to mechanically break the magnet circuit at carbon points outside the machine during the time the brush rested on that bar. This gave a large and powerful spark about 3" long at the carbon points.



Calculation for the winding of two small arc-milling magnets to overhang the large radial machine as collectors.

The diam: of the magnet cylinder is about 29 mm and the ~~length~~ width of the the magnet is also 29 mm: so that the face area of the magnet is approx: $91 \times 30 = 2700$ sq mm. Allowing 20 kg mm to the Watts, this gives 135 Watts which at 50 volts pressure represent 2·7 amperes. so that the res: must be $\frac{50}{2.7} = 18.5\,\omega = 9.25\,\omega$ per limb.

Taking the depth of winding as ½" (1·27 mm) the ceiling space on each limb $= 2 \times (29 + 6.35) \times 17.00 \times 1.27$

$$= 34 \times 35.35 \times 1.27$$

$$= 1530$$

$$d = -\frac{r}{2} + \sqrt{\left\{\frac{r^2}{4} + 0.00153\sqrt{\frac{1530}{9.25}}\right\}}$$

$$= -0.02 + \sqrt{0.00042 + 0.00153\sqrt{165.4}}$$

$$= -0.02 + \sqrt{0.00042 + 0.00153 \times 12.86}$$

$$= -0.02 + \sqrt{0.00042 + 0.0197}$$

$$= -0.02 + \sqrt{0.02001}$$

$$= -0.02 + 0.142$$

$$= 0.122 \text{ cm} = 0.048'' = \#18 \text{ B.W.G.}$$

res: $= 0.0043\,\omega$ per foot $\div$ 1·69 lbs. per ω $\quad 1.69 \times 9.25 = 15.62$ lbs on each limb.
The thickness of the wire covered $= 0.048 + 0.012 = 0.06''$
$= 100$ turns to the layer and 8 layers $= 800$ turns on each limb.
The mean turn has a length of $\frac{70.7 + 72.7}{2} = 71.7$ cms. $= 97360$ mm.
$= 1900$ ft. With 8 layers $= 800$ turns $= 64230$ cms $= 2150$ feet @ 0·00727 lbs per ft $= 15.6$ lbs:

Result therefore 31·2 lbs: of #18 B.W.G. 0·048" with 8 layer of 100 turns on each limb.

Result of Magnet #1 wound with this wire res 19·25 w/o 21°C

Relation of μ to β for different kinds of iron

Jamieson, quoting from Silvanus Thompson gives the relation
wrought iron $\mu = (17000 - \beta) \div 3.5$ for values of β between 16000 & 6000
Aspton Perry) give $\mu = 5221 - 0.3071\beta$ - - - - - 16000 & 10000
For grey cast iron $\mu = 53$ @ 10,000

The Edison Machine Works make Sprague motors of 12½ HP weighing 1450 lbs: and place two upon each large car.

To find the load of greatest commercial efficiency of a motor

Let P be the power supplied to the motor
p - - - " by the "
f - - - wasted - - - in friction
E - - emf assumed constant at the motor terminals.
Then if the motor is run light and takes a current γ,
$E\gamma = f + \gamma^2 r$ where f is the power absorbed + $\gamma^2 r$ is the res: of motor
$f = E\gamma - \gamma^2 r$

At any other load calling for a current c to overcome.

$$Ec = \varepsilon c + c^2 r$$

$$P = (p + f) + h$$

$$p = P - f - h = Ec - E\gamma + \gamma^2 r - c^2 r$$

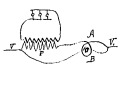
$$\therefore \frac{p}{P} = \frac{Ec - E\gamma + \gamma^2 r - c^2 r}{Ec}$$

$$\therefore \frac{d\left(\frac{p}{P}\right)}{dc} = \frac{Ec(E - 2cr) - E\left(Ec - E\gamma + \gamma^2 r - c^2 r\right)}{E^2 c^2}$$

The energy wasted in heating the armature is equal to the friction assumed constant at all speeds

for max: $\quad E^2 c^2 - 2Ec^2 r = E^2 c^2 - E\gamma E + E\gamma^2 r - Ec^2 r$

$$\therefore -Ec^2 r = -E\gamma E + E\gamma^2 r \quad \therefore c^2 r = E\gamma - \gamma^2 r = f$$



Let A be the coarse coil of the Wattmeter
B . . fine . . . connector
P . . primary . . . connector
r_1 . . . res. including that of A
r_2 . . resistance of B
L_1 . . inductance . .
L_2 . . " . . P and A
e . . p.d. between V and V.
E . . max. value of e.

Then $\varepsilon = E \sin \omega t$ by hypothesis where $\omega = \frac{2\pi}{T}$ and T is the period

$i_1 = A_1 \sin(\omega t - \psi_1)$ where $\psi_1 = \tan^{-1} \omega \frac{L_1}{r_1}$

$i_2 = A_2 \sin(\omega t - \psi_2)$ " $\psi_2 = \tan^{-1} \omega \frac{L_2}{r_2}$

If δ be the reading obtained

$$\delta = \frac{K}{T} \int_0^T i_1 i_2 \, dt$$

$$\delta = \frac{K}{T} A_1 A_2 \int_0^T \sin(\omega t - \psi_1) \sin(\omega t - \psi_2) \, dt$$

$$= \frac{K}{T} A_1 A_2 \int_0^T (\sin \omega t \cos \psi_1 - \cos \omega t \sin \psi_1)(\sin \omega t \cos \psi_2 - \cos \omega t \sin \psi_2) \, dt$$

$(\sin^2 \omega t \cos \psi_1 \cos \psi_2 - \sin \omega t \cos \omega t \cos \psi_1 \sin \psi_2 - \sin \omega t \cos \omega t \sin \psi_1 \cos \psi_2 + \cos^2 \omega t \sin \psi_1 \sin \psi_2)$

$(\sin^2 \omega t + \cos^2 \omega t) \cos \psi_1 \cos \psi_2 - \cos^2 \omega t \cos \psi_1 \cos \psi_2$

$+ (\sin^2 \omega t + \cos^2 \omega t) \sin \psi_1 \sin \psi_2 - \sin^2 \omega t \sin \psi_1 \sin \psi_2$

$- \sin \omega t \cos \omega t \, (\cos \psi_1 \sin \psi_2 + \sin \psi_1 \cos \psi_2)$

$$= \cos \psi_1 \cos \psi_2 + \sin \psi_1 \sin \psi_2 - \cos \psi_1 \cos \psi_2 + \sin^2 \omega t \cos \psi_1 \cos \psi_2 - \sin^2 \omega t \sin \psi_1 \sin \psi_2$$
$$- \sin \omega t \cos \omega t \, (\cos \psi_1 \sin \psi_2 + \sin \psi_1 \cos \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 + \sin^2 \omega t \, (\cos \psi_1 \cos \psi_2 - \sin \psi_1 \sin \psi_2) - \sin \omega t \cos \omega t \, (\sin \psi_1 \cos \psi_2 + \cos \psi_1 \sin \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 + \sin^2 \omega t \cos(\psi_1 + \psi_2) - \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 + \cos(\psi_1 + \psi_2) - \cos^2 \omega t \cos(\psi_1 + \psi_2) - \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 + \cos(\psi_1 + \psi_2)(1 - 2 \sin^2 \omega t) + \sin^2 \omega t \cos(\psi_1 + \psi_2) - 2 \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$\sin \psi_1 \sin \psi_2 \quad \overline{\text{or}} \quad \cos(\psi_1 + \psi_2) \cos 2\omega t \quad \overline{\text{or}} \quad \sin 2\omega t \sin(\psi_1 + \psi_2) + \sin^2 \omega t \cos(\psi_1 + \psi_2)$$

$$+ \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$= \sin \psi_1 \sin \psi_2 - \cos(2\omega t - \psi_1 - \psi_2) + \sin^2 \omega t \cos(\psi_1 + \psi_2) + \sin \omega t \cos \omega t \sin(\psi_1 + \psi_2)$$

$$= \frac{\cos(\psi_1 + \psi_2)}{2} + \sin \psi_1 \sin \psi_2 - \cos(2\omega t - \psi_1 - \psi_2) + \frac{2 \sin^2 \omega t \cos(\psi_1 + \psi_2) - \cos(\psi_1 + \psi_2)}{2} + \frac{\sin 2\omega t \sin(\psi_1 + \psi_2)}{2}$$

$$= \frac{\cos(\psi_1 + \psi_2)}{2} + \sin \psi_1 \sin \psi_2 - \cos(2\omega t - \psi_1 - \psi_2) + \frac{\cos 2\omega t \cos(\psi_1 + \psi_2)}{2} + \frac{\sin 2\omega t \sin(\psi_1 + \psi_2)}{2}$$

$$= \frac{\cos(\psi_1 + \psi_2)}{2} + \sin \psi_1 \sin \psi_2 - \frac{\cos(2\omega t - \psi_1 - \psi_2)}{2}$$

$$= \frac{\cos \psi_1 \cos \psi_2 - \sin \psi_1 \sin \psi_2}{2}$$

$$= \frac{\cos(\psi_2 - \psi_1)}{2} - \frac{\cos(2\omega t - \psi_1 - \psi_2)}{2}$$

$$= \frac{K}{2T} A_1 A_2 \int_0^T \cos(\psi_2 - \psi_1) - \cos(2\omega t - \psi_1 - \psi_2) \, dt$$

Alternating Current Converters.

Data collected concerning them from various sources.

If n_1 and n_2 are the numbers of turns of wire in the primary (secondary) circuits respectively of a converter of closed magnetic circuit, the coefficients of self and mutual inductance are in the ratio

$$n_1^2 : n_2^2 : n_1 n_2$$

A good rate of working is 100 ~ per sec.

If the alternations be increased n times the wire may be reduced $\sqrt{n}$ times roughly or the emf rise roughly by that amount.

In an ordinary transformer the wire is said to average in either circuit from 1·5 to 2 ~~feet per~~ volts per foot. The initial current in the primary with the secondary open should not exceed 0·05 amperes.

The induction $\mathfrak{B}$ should not be above 10,000 lines per sq. cm.

A fair average is 7000

Pinnington's method of measuring the power supplied to the primary coil of a transformer by means of a Siemens dynamometer

$$p = K \delta \frac{r_1 (r_2^2 + \omega^2 L_2^2)}{r_2 (r_1 r_2 + \omega^2 L_1 L_2)}$$

(Wattmeter) whose continuous current constant is K, and δ is the deflection:

where r_1 is the ohmic res. of the primary + that of the coarse coil of Wattmeter
r_2 . . . . . ~~secondary~~ fine coil of Wattmeter
L_1 . . inductance . . . primary + that of the coarse coil of Wattmeter
L_2 . . . . . ~~secondary~~ fine coil of Wattmeter.
ω . . $\frac{2\pi}{T}$
δ . . brown reading
K . . constant of the inst. for continuous currents
p . . power absorbed by the primary in Watts including the ~~[illegible]~~ watts

An allowance of 20 sq. cm. per Watt should be given to transformers for the total heat generated therein.

The weight of a transformer varies from 10lbs to 50lbs per HP

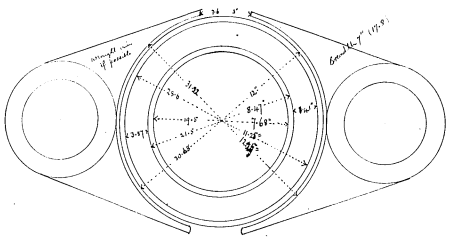
. efficiency of a good transformer is 96% at full output and 90% at 1/4 full output.

For a parallel transformer to be effective in regulation the drop in the secondary at full load should not exceed 1% of the mean secondary and similarly the drop in the primary due to ohmic res. should not exceed 1% of the mean primary emf.

The diam. of the wire should not exceed 250 mils, if greater be required it should be subdivided to avoid creation of vortices.

At 27000 and 100 ~ the hysteresis is given at 3700 ergs per cubic inch per cycle or 37 Watts per cubic decimeter of iron. ~~[illegible]~~

Section of the armature by plane ⊥ axis
scale 1/8" to the cm.
about 1/4 actual size



Particulars of Motor

Dimensions

Length over all	32.6 cm	12.7"
Breadth - -	66.2	25.8"
Length of core	20.3	8"
Diam. - -	11.3	4.4"
Yoke Section	12.1 x 14.7	4.75" x 5.8"

Armature

Breadth of ring	17.8	7"
Diam. over all	32.6	12"
Thickness of winding	2.92	1.15"
Clearance	0.52	0.15"
Thickness of ring	3.57	1.4"
Diam. ring out	28.6	11.25"
" " int	21.5	8.47"
" interior of ring	18	7"
Space between pole pieces	7.6	3"

Weight

28" of core cm. 11.3 x 7.6 = 2.12 lb	
poles estimated	20
22" of weight of 2.92 x 7.8 = 1.14	1.90
field winding	27
armature	50
" cm. 7.6 x 2.92 = 1.14	1.90
Commutator & shaft	17.0
Total	119

Magnetics.

Total flux 2,375,000
Leakage allowed 20%
Useful flux 1,900,000
ϕ in core 11,000 per cm²
ϕ in yoke 6,000 " "
ϕ in armature 11,000 " "

Winding

Armature

E.M.F. 12.8 volts. 0.165
Ewatts on Armat. watts 88
" " " watts 8
Number of Armat. cm each half ring 66
" " " in all 66
cross-section wire

Field

Each core of length of 28 turns wire
ϕ 0.165 Total length 924 Total lb
924 turns 1.3 ohm current 1 amp
depth of winding 1.5
Total wire each field 1.3
Turns in series = 1.3 = 5 amperes
= 3150 ampere turns per limb
= 1.3 amp
= 7850 exciting turns in all
Total reluctance 0.0061 limb

Motor Calculations

continued from page 43.

Taking 2000 ft per min as the peripheral speed of the armature = 9000000 per min or 1500 cm per sec. we may arrange the winding more favourably. With six wires their size must be $\frac{145000}{6}$ = 24,100 nearest to B.W.G. each 0.165" covered 0.180" (0.419 cm) cm 0.457 cm), three wide and two deep = 0.36" or 0.914 cm deep and 0.54" or 1.371 cm wide. The diam. of the drum being 30.48 cm, at the centre of the winding it will be 29.67 cm. and the corresponding surface = 92.99 cm which allows for $\frac{92.99}{2 \times 1.371}$ = 33.9 turns on each side of the whole cylinder each half ring say 33. Then with a breadth of 15.2 cm the average field required to generate 20 volts will be $15.2 \times 33 \times 1500 \times f = 20 \times 10^8$ or $f = 2657$ = 26.57 gauss. The area of the pole-faces, armature half surface will be $\frac{30}{2} \times \pi \times 15.2$ cm = 716 sq. cm so that the total flux must be 716 x 2657 = 1,902,000 usefully employed.

The thickness of the ring may be taken as 0.25 r where $r = \frac{30.48}{2}$ = 0.95 = 14.24 = 7.57 and the internal diameter therefore (22.86) which reduced by 0.95 gives 19.54 as the diam. of the inside winding or circumference of 61.3. This allows the three x 2 turns to lie inside 2 x 3.

The thickness of the iron ring being 3.57 and its length 15 the magnetic area is 1071 sq. cm. Of this some 20% may be allowed for insulation leaving 857 sq. cm for conduction and this represents an induction of 22,000 lines per sq. cm. This is excessive.

Taking the length of the cylinder at 7" (17.8) the average field has to be only $26.57 \times \frac{6}{7}$ = 22.78 gauss and the total flux remains unaltered. The magnetic area has correspondingly increased so that the induction is $\frac{22000 \times 6}{7}$ = 18,800 lines which is not excessive.

Allowing 20% for leakage the total flux to be provided for is 1,902,000 + 475,000 = 2,375,000 lines

Let us assume 12,000 lines per sq. cm. in the magnets. Then the area of the magnet cores must be 200 sq. cm.

The corresponding density in the cast iron may be taken as 6000 which gives 400 sq. cm. As there are two magnetic circuits the cores must have 100 sq. cm. each and the yokes 200. The cast iron pole pieces must also have 500 say. The diameter of the core must therefore be 11.3 cm. = 4.45" say 4.5". The winding depth may be made 1" as a trial value. Then the diam. of the whole magnets overall will be 6½" (16.52). The trial length of the core may also be made 8" (20.3). Then the width of the cast iron yoke will be at least (6½)(16.5) so that at that width the thickness should be $\frac{200}{16.5}$ = 12.1 cm. (4.85")

The reluctances must now be as follows:—

				$\frac{L}{m}$	μ	rel.
In the armature the mean length will be 17.8 cm			area 127 sq. cm.	0.0778	60	0.00233
" "	pole pieces	length	2 x 18	0.22	500	0.000140
		area	180			
" "	cores	length	20.3	0.20	1400	0.000142
		area	100			
" "	yokes	length	½(47.7)	0.119	250	0.000476
		area	200			
" "	clearance	length	2 x 0.52	0.00268	1	0.00268 0.00268
		area	190			
" "	winding	length	2 x 0.92	0.00212	1	0.00212 0.00212
		area	870			
					Total reluctance	0.006161

The required flux is 2,375,000

and $\frac{1.257}{0.006104}\, a.T. = 2.375 \times 10^6$

$$\therefore\ aT = \frac{2.375 \times 10^6 \times 0.6104 \times 10^{-2}}{1.257} = 11530 \text{ on each pair of limbs.}$$

If now we have 3.8 times as many, then the iron will be saturated and where the voltage falls on a heavy load the field will be weakened. Let the a.T be therefore 34660 on each pair or 17320 on each pair of cores. The surface of the cores is 20.3 × 50 = 1000 sq. cms (bet) and with 16 (Watts per sq. cm) 100 Watts may be allowed = 5 amperes at 20 volts = 4 w. in all, 2 w each.

The ceiling space is for one 20.3 × (213.8 − 100.3) = 20.3 × 113.5 = 2304 c.c. The diameter of the wire is thus

$$d = -\frac{t}{2} + \sqrt{\left\{\frac{t^2}{4} + 0.00753\sqrt{\frac{2300}{2}}\right\}}$$

$$= -0.02 + \sqrt{\{0.0004 + 0.00153 \times 38.73\}}$$

$$\sqrt{\{0.0004 + 0.05924\}}$$

$$\sqrt{(0.05964)}$$

$$D\ 24443$$

$$= 0.2244 \text{ cms.} = 0.088'' \quad \text{nearest \# above } 0.095'' \ (\text{\# } 13.\ \text{B.W.G.})$$

with 23.9 lbs. per w. and 47.8 lbs. on each limb.

If all four coils be in series that is have 1w each

$$d = -0.02 + \sqrt{\{0.0004 + 0.00153\sqrt{2300}\}}$$

$$\sqrt{\{0.0004 + 0.0734\}}$$

$$\sqrt{(\ \ 0.0738\ \ )}$$

$$D\ 272$$

$$= 0.252 \text{ cms} \quad 0.100'' \quad \text{nearest \# } 0.095'' \ (\text{\# } 13\ \text{B.W.G.})$$

with 23.9 lbs. per w and 95.6 lbs. on all four limbs together.

The length is 8714 feet and the mean turn has a diameter of 13.9 cms 4.367 cms so that the no. of turns on each limb is $\frac{26660}{4.367} = 610$ and the ampere turns 3050

The res: of the armature will be:—

48 cms per turn + 33 turns = 1584 cms. of 6 #8 wire on each half ring = 264 cms of #8 wire on each half ring = 132 cms of #8 wire equivalent = 4.33 feet × 3.79 × 10^{-4} = 16.4 × 10^{-4} = 0.00164 ohm

9.66 feet of 6 #8 wire = 10 feet of #8 wire = 0.0326 = 32 ohm. 22 = 24 ohm

The drop in the armature at 600 amperes = 10 volts = 6000 Watts.

loss in the field is 5 amperes @ 20 volts say = 100 –

Calculation of electrical efficiency of the system.

			Watts.
Energy delivered at fine wire terminals of transformer @ 14 ampere =			14000
Heat lost in fine wire armature at full load		1570 Watts	
600 4.66	" " coarse " " " " "	2810	
	Waste in transformer armature	4380	
	" " " magnets 174 × 15	2610	
		6990	f Work 33.2
	Waste in motor at full load	6000	
	field magnets	100	
		10744	f. Work 76.7 10740
	1.4# must probably be allowed for friction leaving 18# for use.		less than 5 # 3260

With 100 amp. delivered by transformer = 74 Watts in coarse 20 in fine wire 300 in magnets 400 Watts. in motor full 100 armature 16 . 520 in all out of 2600 the work being only 25%

Table of Observed variations of Specific Gravity with temperature in $ZnSO_4$ solution of 1.11 @ 20°c

Temp:	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55	60°	65°	70°	75°	80°
Sp. Gr.	1.1140	1.1135	1.1125	1.1115	1.1100	1.1055	1.1070	1.1055	1.1040	1.1015	1.0995	1.0970	1.0940	1.0910	1.0880	1.0850	1.0820
Δ		0.0001	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0005	0.0002	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006
Corrected Sp. Gr.	1.1140	1.1135	1.1125	1.1115	1.1100	1.1055	1.1070	1.1055	1.1040	1.1020	1.0995	1.0970	1.0940	1.0910	1.0880	1.0850	1.0820
Δ		0.0001	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0001	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006

0° to 5°	0.0001	0
5° - 15°	0.0002	10
15° - 40°	0.0003	30
40° - 45°	0.0004	40
45° - 55°	0.0005	50
55° - 75°	0.0006	65

Assuming the empirical formula

$$d_t = a + bt + ct^2$$

we have

$$\left.\begin{aligned} d_{1100} &= 1.1140 + 20b + 400c \\ 1.0880 &= 1.1140 + 70b + 4900c \end{aligned}\right\}$$

$$20b + 400c = -0.0014$$
$$70b + 4900c = -0.026$$
$$2b + 20c = -0.00020$$
$$b + 70c = -0.000371$$
$$50c = -0.000171$$
$$c = -0.0000342$$
$$b = -0.000684 + 0.000200$$
$$= -0.000484$$

$$d_t = 1.1140 - 0.000484t - 0.0000034t^2$$

$$d_{15} = 1.1140 - 0.00132 - 0.000034$$
$$- 0.00166$$
$$= 1.11234 \quad 1.110 \text{ against } 1.1125$$

$$d_{30} = 1.1140 - 0.00263 - 0.00036$$
$$- 0.00299$$
$$= 1.1093 \text{ against } 1.110$$

$$d_{50} = 1.1140 - 0.00395 - 0.000378$$
$$- 0.00703$$
$$= 1.107 \text{ against } 1.107$$

$$d_{60} = 1.1140 - 0.00526 - 0.00544$$
$$- 0.01070$$
$$= 1.1033 \text{ against } 1.104$$

$$d_{70} = 1.1140 - 0.00658 - 0.00855$$
$$- 0.0151$$
$$= 1.099 \text{ against } 1.0995$$

$$d_{80} = 1.1140 - 0.00790 - 0.0123$$
$$- 0.0202$$
$$= 1.0938 \text{ against } 1.0940$$

$$d_{90} = 1.1140 - 0.00921 - 0.0171$$
$$- 0.0263$$
$$= 1.0877 \text{ against } 1.088$$

$$d_t = 1.1140 - 0.000484t - 0.0000034t^2$$
$$1.1140 - 0.000484t\,(1 - 2.6t)$$
$$= 1.1140 - 1.316t \times 10^{-4}\,(1 - 2.6t)$$

The weight of the Siemens Altg. Current Dynamo in the Dynamo room is 711 lbs.

In the transformer itself if V and v are the electrical pressures at the primary & secondary terminals we have:

(1) $V = E + c_1 r_1$
(2) $v = \eta - c_2 r_2$
(3) also $V = nv$
(4) and $\frac{n}{1} c_1 = \frac{1}{n} c_2 + f$

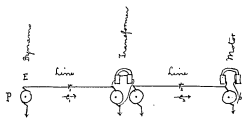
hence (1) $E = V - c_1 r_1$
(2) $\eta = \frac{V}{n} - c_2 r_2$
(4) $c_1(V - c_1 r_1) = \left(\frac{V - c_2 r_2}{n}\right) c_2 + f$
$\therefore f = (c_1 - \frac{c_2}{n})(V - c_1 r_1)$

$$E = \frac{V}{n} - \left(c_1 \frac{r_1}{n} + c_2 r_2\right)$$
neglecting friction & eddies

$$= \frac{V}{n} - c_2\left(r_2 + \frac{r_1}{n^2}\right)$$

also $v = \frac{V}{n} - c_2 \left\{\frac{r_1}{n^2}\left(1 + \frac{f}{c_2 v}\right) + r_2\right\}$ taking friction & eddies into account.

$$= \frac{V}{n} - c_2\left[\frac{E}{n} + \frac{r_1}{n^2}\left\{1 + \frac{f}{c_1(V + c_1 r_1)}\right\}\right]$$



To find the maximum power capable of being yielded by a given value of E we have the relation

$$\frac{dp}{dc_1} = E - 2c_1(r_1 + n^2 r_2)$$

so that $E = 2c_1 r_1 + 2nc_2 r_2$

or $E = 2c_1(r_1 + n^2 r_2)$

$E = 2c_2\left(\frac{r_1}{n} + nr_2\right)$

whence $c_1 = \frac{E}{2(r_1 + n^2 r_2)}$ $\quad c_2 = \frac{E}{2\left(\frac{r_1}{n} + nr_2\right)} = \frac{nE}{2(r_1 + n^2 r_2)}$

assuming that the second line has a negligible resistance. Now if the transformer had been used directly as a motor the maximum power would have been obtained from a current of $\frac{E}{2r_1}$ at an efficiency of 50%. By transforming however besides the extra waste in field magnetism and the second motor friction the maximum power is given by a further current in the ratio of $r_1 : (r_1 + n^2 r_2)$ where n is the coefficient of conversion, with a correspondingly reduced efficiency. For example in the car motor system lately calculated for in this book $n = 50$ $r_1 = 8\,\omega$ and $r_2 = 0.008\,\omega$ so that with $E = 1000$

$c_1 = 18.2$ @ 36.5% efficiency $= 5110$ Watts delt.

while if the transformer had been used as a motor the best value of

$c_1 = 62.5$ @ 48% efficiency $= 29{,}000$ Watts delivered

Efficiency of a Motor cont. from page 45.

With the same notation as on page 45

If P be the power supplied to the motor
" p " " " by " "
" f " " " absorbed by " " in friction (constant at all loads)
" h " " " " " " heat
" m " " " " " " supplying its field.
" γ " " current required to run the motor unloaded
" E " " emf. of the source

Then $E\gamma = m + f + \gamma^2 r$

and by (precisely) similar reasoning to that on page 45

$\frac{p}{P}$ or the efficiency when $c^2 r = m + f = E\gamma - \gamma^2 r$

so that the heat waste in the armature equals the total energy expended in running the motor light.

In the next case let us consider a continuous transformer system consisting of a motor dynamo supplied by an inconstant E.M.F. at machine primary terminals with a constant field and delivering a corresponding supply of low pressure current, through its own armature line and a motor of constant field.

Let E be the electrical pressure at the dynamo end
P " " power electrically taken from the source E
r_1 " " resistance of the line and primary of the transformer
r_2 " " resistance of the second line, the secondary of the transformer and the armature of the motor
f " " power wasted in overcoming the friction of the transformer together with the resistance of eddies
φ " " power wasted in overcoming the friction of the motor both mechanical and magnetic
m " " power constantly consumed in exciting the field of the transformer
μ " " power constantly consumed in exciting the field of the motor (m and μ are not quite constant but are sufficiently nearly constant for practical purposes)
p " " power given out by the motor.

Then $P = p + c_1^2 r_1 + f + m + c_2^2 r_2 + \varphi + \mu$

$= p + c_1^2 r_1 + c_2^2 r_2 + K$

But if ε be the counter emf. of the primary coil of transformer and η " " generated emf of the secondary " "

$\varepsilon c_1 = \eta c_2$ $\quad$ let $\frac{\varepsilon}{\eta} = n$ $\quad$ Then $c_2 = nc_1$

$$P = p + c_1^2 r_1 + n^2 c_1^2 r_2 + K$$

$$\therefore p = Ec_1 - c_1^2(r_1 + n^2 r_2) - K$$

$$\frac{p}{P} = \frac{Ec_1 - c_1^2(r_1 + n^2 r_2) - K}{Ec_1} = \frac{E - c_1(r_1 + n^2 r_2) - \frac{K}{c_1}}{E}$$

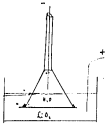
$$\frac{d\left(\frac{p}{P}\right)}{dc_1} = \frac{Ec_1\{E - 2c_1(r_1 + n^2 r_2)\} - E\{Ec_1 - c_1^2(r_1 + n^2 r_2) - K\}}{E^2 c_1^2}$$

for maximum $\quad c_1\{E - 2c_1(r_1 + n^2 r_2)\} = Ec_1 - c_1^2(r_1 + n^2 r_2) - K$

$\therefore K = c_1^2 r_1 + n^2 c_1^2 r_2$

$= c_1^2 r_1 + c_2^2 r_2$

Hence to obtain the maximum efficiency from such a system the energy wasted in the lines and armatures must be equal to the energy spent in exciting the magnets and overcoming the mechanical friction; in other words the variable and fixed losses of energy must be equal.



Electro-medical experiment on Lithium.

Observer Lehmann. 9th Sept: 89

A glass funnel of 7.5 cms diam: at aperture was closed by a piece of sheep bladder a mm thick, thus giving a porous diaphragm of 44.229 cms. This funnel was filled with slightly acidulated water and a platinum wire passing through the tube formed the negative electrode. The whole was then immersed about 1 cm. below the surface of a 2½% solution of Li_2O_3 but above the bottom of the dish about 1.25 cms. A second platinum wire formed the + electrode. A current of 0.15 amperes was then passed through the apparatus for 75 minutes. The funnel was then removed and emptied. The contents were mixed with a solution of Na_2PO_3 and the mixture evaporated to dryness. The residue was then heated with water to dissolve the sodium salt and left for 12 hours. The final precipitate was found to contain 0.5 grammes of Li_2PO_3.

The experiment was repeated under similar conditions without employing the current. After 75 minutes immersion the same treatment repeated gave for diffusion 0.3 grammes of Li_2PO_3 so that it was supposed that the current had been the cause of the action 0.2 grammes being transferred in the first experiment by endosmose. 0.2 gm Li_2PO_3 represent 0.061 of Li_2 and 0.131 of Li_2O.

Batteries.

A phonograph NaHO battery of four cells which had been discharged once was employed to run a cast iron armature. It was kept operating during the day time and taking off a chip continually. It failed to take a chip at speed after 50 hours work. This being an unfavorable result, repeated test.

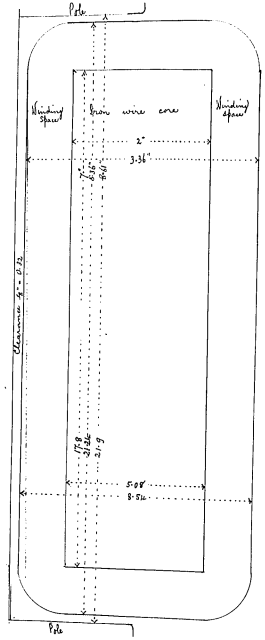
These phonograph cells of the large type are stated by Mr Gladstone to have an average EMF of 0.64 volt and an int: res: of under 0.03 ω (0.025 to 0.03.)

Two phonograph cells (NaHO) of the small type were compared with a Leclanché cell. The phonograph cells had the following dimensions. The glass jar has a height to the neck inside 13 cms 5⅛". Diameter inside 7 cms = 2¾". Diam: of neck inside 4.7 cms = 1⅞", closed with a paraffinide cork. Zinc plate (not) length 16 = 6⅜" diam: 0.9" = 0.6". Copper peroxide plate length 12 cms 4⅞" breadth 1.7 cms = 0.75". Thickness 0.8 = 1/32".

In the first trial, the clock automatically changing the battery every five mins: on 2ω. The NaHO cell failed after 72 hrs, and the Leclanché after 18 hours. In the second trial with the same cells and plates but with the liquid renewed, the NaHO became exhausted after 68 hours (30 actual work) did not even at starting recover. Records on Burns Book. No. 10. of Burns Book.

The model for the small zinc water plate was completed on Saturday afternoon the 14th September. It was taken to Silver Lake and the plate remained caught. The bristles were good hold, but the plate reduced with Zinc only about 1½% as 1/8" = 4/32, became reduced about 1/32nd.

Full size section of armature parallel to axis. also pole piece



Length of lowest armature turn		45.76	18"
" " uppermost	" "	59.56	23.44
" " mean	" "	52.66	20.72

Problem. To so modify the Transformer designed on pages 37 and 39 as to let it supply two motors of the design given on page 47 with 7 HP each at full load.

If the res: of the primary coil of the transformer be 5 ω and " " secondary circuit (joint res:) 0.0175 ω

Then the maximum amount of work will be done when a the secondary circuit current $= \frac{48000}{2(5+2500\times 0.0175)} = 1060$ amp.

Taking the energy lost in the coils by heat @ 50% or in other words the res: of the coil as 50% of the secondary circuit res, the energy required at arc as follows. available for car 7 HP 5250 Watts

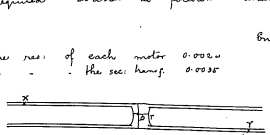
" " magnet 100 "

" " motor friction 250 "

Energy absorbed by car motor 5600 "

The res: of each motor 0.002 ω

" " " the sec: transf. 0.0035



If T be the position of the transformer X and Y be two cars supported at full limit distance of l feet. Then the res: of the secondary ckt =

transformer sec:	0.0035
two motors in ∥	0.0010
two lines in ∥	0.00267
	0.00767

The energy lost at full load in the transf: sec. $= (1060)^2 \times 0.003 = 3370$

" " " " " " " " " line $2(530)^2 \times 0.00767 = 4125$

" " " " " " " " " motor $2(530)^2 \times 0.002$ 1120

Heat waste 8615

Car motor supplies 11400

Transformer secondary absorbs 20000

Fall of potential in transformer secondary 3.18 volts P.D. at terminals 16.82

" " " " line 3.89 " " " motor 12.93

" " " " motor armature 0.53 " " " " 12.43

electrical efficiency of motor $\frac{12.40}{12.93} = 0.96$

commercial efficiency of motor $\frac{5250}{5700} = 0.92$ ∴ $\frac{5250}{6260} = 0.84$

efficiency of system from transf: sec: to motors 0.57

The winding is therefore required of a transformer whose pr: and sec: res: shall be 5 ω and 0.003 ω the generated emf to be not less than 20 volts at full load and to be little above 20 volts when running light. The ampl: of current to be 48

The armature to be divided into 360 equal parts 180 for each circuit and the pr: + sec: winding alternate 90 bars in each circuit, and the pr: + sec: winding alternate 90 bars in the secondary commutator or 1 to each two blocks. 180 bars in the fine wire or primary commutator or one to each block. The ring to be 7" broad on the iron wire and 2" thick. (17.8 + 5.1)

If #13 B.W.G. be employed for the coarse winding in six layers of two turns each. the length of the mean turn being 1.728 feet and the res: 1.2×10^{-3} ω per foot $= 207 \times 10^{-3}$ ω per turn $= \frac{2.07 \times 48}{48}$ $= 0.0014$ ω in all and with connections 0.003 ω the area of the wire is 9025 cmc + 48 carry the current $= \frac{48 \times 9025}{1060} = 410$ cmc per ampere.

The diam: of #13 B.W.G. is 0.095" = 0.110" covered, and the wire with = 0.220" + 3 thickness of paper = 0.232" + the wire of diam 0.042" (#19 B.W.G) = 0.055" covered = 0.452 × 180 = 81.36" circumference = 25.9" say 26" diam: internal + 30" diam: external.

The fine wire coil has a resistance of $\frac{45}{60} \times 48 \times 1.728$ feet of #19 B.W.G = $5.40 \times 1.728 \times 5.852 \times 10^{-3}$ = 5.46 ω say 5.5 ω perhaps 6 ω hot.

#19 wire has an area of 1760 cmc + 60 carry the current = 7056 cmc. and with an efficiency of 90% + 20,000 Watts generated in the secondary ckt the energy absorbed in the primary = 22,200 Watts @ 960 volts = 23.14 amps = 305 cmc per ampere. 23.14 × 6 = 139 volts drop in armature = 1100 volts at machine terminals.

Particulars of Transformer.

Length	31·6"	9·6
Breadth	22·4"	5·2·3
Height	34·5"	8·7·6
Length of core	12"	30·5
Diam.	7·5"	19·1
Space between limbs	3"	7·6
Yoke (inside)	17½"	44·5
(outside)	22·4"	5·2·3
Breadth	7·5	19·1
Thickness	3"	7·6
Clearance	2"	5·1
Length of poles for		62·6
Diam. of magnets for	3·5"	9·0·8
	2·5"	6·4·0
. . windings	(for 31·0) (for 24·0)	79·37 62·5
Breadth of wing	7"	17·8
over core	5·16"	21·0
Thickness of wing	2"	5·1
over core	3·36"	8·5

Magnetic data.

Useful flux 1585000

Leakage allowed 391000

Total calculated for 1976000

$\mathcal{E}$ in core 6790

. armature 21600

Reluctance of winding-space 0·0086

. rest ck 0·0032

Size of wire no magnet # 22 B.W.G. 0·028"

Total weight per core 164·2 lbs.

Total weight magnet wire 134 lbs

Winding space 11" long 1" deep

33 layers of 300 turns per layer.

Amperes in field 0·605

Turns of wire 8000

Ampere turns 5250.

Weight

2 core each 44·2×12 = 530 c.i. = 138 lbs = 552

2 frames each (102·3 − 30·5) × 70 × 3 = 22362 . . . 1,150

1 wing = 70 − 33 = 17·4 sq.in × 7·1323 = 123 c.i. 308

secondary wire 190×2·4×12 = 10,900 ft . 60

primary . 180×12×12·6 = 2,720 . 76

shaft + commutator . 200

Bolts + frames bearing + plumbing 600

3000 lbs total wt. 3412

Commutator

180 bars for primary

30 . . sec ckt

Winding of commutator

180 bars of pri #19 B.W.G. 12 layers of 15 turns in each

180 . . sec . #13 . 6 . . 2 . . in

Res. of primary ckt. 6·0 ohl

. . sec . 0·003

Max. energy in sec. at full load 3370 watts

Current . . . . 1060 amperes

Current in primary . . . 23·1 .

Max. energy . . . . 3200 watts

Drop of pot. at full load in sec 3·18 volts

. . . . pri 139 volts

P.D. at terminals of sec full load 16·8 .

. . . . pri . 1100

Energy delivered to lin. at full load 254410

. . . magnets . . 2700

257110

Delivered loss in friction 2000 watts

. . . . for 3200

. . . . sec 3370

. . . . line 4125

. . . . motor 1120

. . . . magnet 2700

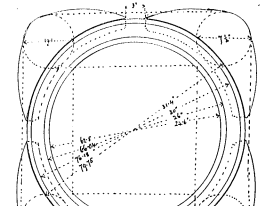
. . . . friction 700

14215

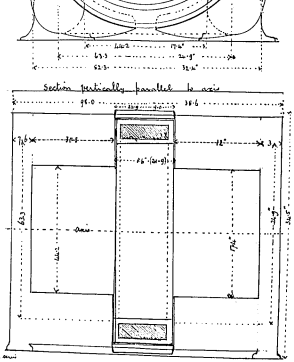
= watts consumed 254710 + 10700 available

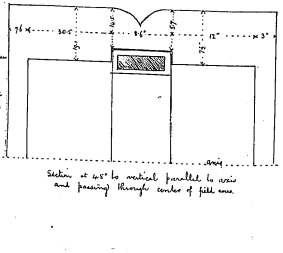
efficiency of 96½ %

Vertical section at right angles to axis.



Section vertically parallel to axis





Section at 45° to vertical parallel to axis and passing through centre of field coils.

Magnetic circuit of Transformer.

The peripheral speed of the armature = 14000 ft per min = 2000 cms per sec and 45 turns in the secondary winding generate 22·5 volts = 0·5 volts (running light) per turn, the effective length of each turn is 29·0 cms and the field necessary is thus $25/2 \cdot 9 \times 10 \times 2 \cdot 0 \times 10^8 = \frac{25 \times 10^8}{5 \cdot 8 \times 10^8} = 862$ amps.

The total length of pole surface is 59 cms and the breadth 31·0. The total length of one quadrant of armature is 62·6 and the breadth 29 cms = 1816 sq. cms = 1,565,000 lines employed. Allowing 25% of this for leakage 391,000 + 1,565,000 = 1,956,000 lines have to be generated. The cores are about 141 cms. and their half mean is 143 sq. cms. $\frac{l}{a} = \frac{141}{143} = 0 \cdot 2761$ for = 1260 p. 500 to 0·0086

Two of these $\frac{l}{a}$ cores are in series + a similar pair in parallel in each circuit so that the reluctance is that of one core 0·0007736

The yoke ckt is about 63 cms long and 145 cms $\frac{l}{a} = \frac{63}{182} = 0 \cdot 4345$

$\mathcal{E} = \frac{1956000}{145} = 6750$ $\mathcal{E} = 500$ $\mu = 0 \cdot 0008690$ lns in ‖ = 0·0004345

The pole is about 12 cms long and 2640 in area $\frac{l}{a} = \frac{12}{2640} = 0 \cdot 05$

then an lns in series = 0·1 ÷ μ 1000 = 0·00010

The air space is ⅓ (0·32) long and area 1900 sq. cms $\frac{l}{a} = \frac{0 \cdot 32}{1900}$ = 0·000356

The armature length is about 20 cms

its area is 0·8 × 5·08 × 17·8 = 72·6 sq. cms. $\mathcal{E} = \frac{1565000}{72 \cdot 6} = 21600$. p. 500

$\frac{l}{a} = \frac{20}{72 \cdot 6} = 0 \cdot 278$ the average value of μ is probably 200 . 0·001390

0·003291

The winding space has a length of 1·75 and a breadth of 1900 sq. cms $= \frac{l}{a} = \frac{1 \cdot 75}{1900} = 0 \cdot 000972 \times 2$ 0·003888

0·007500

To generate 2000,000 lines the exciting power must be 1260 with this reluctance. = 7000 on each core = 5870 ampere turns on each core. To make more certain let us take 6000 ampere turns per core.

Although it is cheaper to some extent to supply the field from the secondary core, yet the tendency to reduce the ampere turns when load comes on the transformer makes it in this case more desirable to supply the field from the primary terminals. The surface of each core is 1800 sq. cms. and allowing 50 sq. cms per Watt gives 36 Watts for each core, as a trial value. With 8 in series there will be 1100 ÷ 8 = 137·5 volts on each. 36/137·5 = 0·262 amperes = 525 ω res. and the total depth being 0·5" = 1·27 cms, the winding space is 11 × 2·54 (317 − 236·5) = 27·94 × 80·5 = 2250 sq. cms

$$d = -0 \cdot 02 + \sqrt{\{0 \cdot 0004 + 0 \cdot 00153 \sqrt{\tfrac{2250}{525}}\}}$$
$$+ \sqrt{\{0 \cdot 0004 + 0 \cdot 00153 \times 2 \cdot 071\}}$$
$$+ \sqrt{(0 \cdot 00317 + 0 \cdot 0004)}$$
$$+ \sqrt{(0 \cdot 00357)}$$
$$+ 0 \cdot 0598 \text{ cms} - 0 \cdot 02$$
$$+ 0 \cdot 04 \text{ cms} = 0 \cdot 016'' = \# 27 \text{ B.W.G.} = 0 \cdot 028'' \text{ cond.}$$

= 0·0492 lbs. per ω = 10·1 lbs. on each core = 84 lbs. in all.

allowing 30 watts to the surface = 40 Watts = $\frac{40}{137 \cdot 5}$ = 0·2909 amp = 13750 turns. With ½" coiling depth = 5·5" coiling area = 5,500,000 cmb ÷ 127·5 = 43,100 cmb = 0·020 × 0·028" copper. To give 0·2909 amp requires $\frac{137 \cdot 5}{0 \cdot 437}$ = 315 ω

$$d = -0 \cdot 02 + \sqrt{\{0 \cdot 00004 + 0 \cdot 00153 \sqrt{\tfrac{2250}{315}}\}}$$
$$+ \sqrt{\{0 \cdot 0004 + 0 \cdot 00153 \times 2 \cdot 673\}}$$
$$+ \sqrt{(0 \cdot 0004 + 0 \cdot 00409)}$$
$$+ \sqrt{0 \cdot 00449}$$
$$-0 \cdot 02 + 0 \cdot 067$$
$$+ 0 \cdot 047 \text{ cms} = 0 \cdot 0185'' = \# 26 \text{ B.W.G.}$$

= 0·83 lbs per ω = 9·45 lbs per core = 75·8 lbs in all.

round the mean turn = 15·13" = 1·26 feet. 31·39 ft per ω @ 315 ω = 9900 ft

= 7850 turns = 31·20 a.T.

allowing 20 sq. cms per Watt gives 0·021" with ½" depth = # 26 B.W.G. 0·022" = 9650 ft per ω = 300 turns per layer

= 33 layers = 1" = 114·24 lbs per core = 134 lbs in all

Taking (2) as correct.

$R = 0.00734$

$c = \frac{1}{10}$

$\frac{Rc}{2} = 36.7 \times 10^{-5}$

$p = 6.0 \times 10^{-5}$ allowing 10% on 10 miles.

$\frac{Rc}{2p} = 6400$

$\frac{Rc}{2p}(t+T) = 6400 \times 250 = 1,600,000$

$\sqrt{6400 \times 250} = 1600$

$\frac{\sqrt{6400 \times 250}}{2} = 620$ ft

∴ the economical distance is 620 feet.

A transformer weighs 3000 lbs if above designs on page 52–53 be accepted, and @ $0.033 lb will cost $1000.

t depreciation annually $100

T interest and superintendence, oil, bushes etc $150

$t + T = 250$

The specific resistivity of iron being 9600 ohm. w. @ 0°C

1 foot of bush 1 sq. in. in section has a resistance of 52 microhms

conductance of 19,230 mhos

1 c.mil foot of copper has a resistance at ordinary temp of 10 ω

conductance " " " of 0.1 mho.

1 " " " " " weight " " 3.018×10^{-4} lbs.

Problem: To Determine the most economical distance between the Transformers, on a double car track

Let t be the depreciation of a transformer yearly in $.

r - - annual interest at current rate not only on the first cost of the transformer but also on the cost of its installation and necessary connection expenses together with the cost of keeping it in order, oil, + bushes $.

D - - distance from one end of the road to the other.

N - - number of car trips per annum (to the end of the track and back)

w - - energy integral, expended in driving a car at full load to the limit or from the limit to the transformer (watts)

c - - conductance of one cir. mil. foot in mhos

k - - " " " foot of iron track . . .

p - - annual price of one cir. mil foot copper in int. + dep. $.

n - - number of cir. mil of copper conductor laid down.

ε - - cost of a watt in the secondary circuit $.

R - - limiting resistance of the track.

x - - distance between the transformers.

It is assumed that each transformer is so loaded during working hours as to supply the full amount of $2w$ watts to each car as it comes over the left hand limit and runs over to the right hand limit. With varying load this is not true, but w may be estimated at a fair average allowance by examination of existing data.

Then the number of transformers is $\frac{D}{x}$

Their total cost per annum is $\frac{D}{x}(t+T)$

The number of discharges of energy in one trip (there + back) $\frac{4D}{x}$

" energy expended on each $\frac{4Dw}{x}$

" expense incurred in supplying this energy $\frac{4Dw\varepsilon}{x}$

" annual " " " " " $\frac{4ND w\varepsilon}{x}$

" " expense incurred on the account of conductor investment is $4Dnp$

Total variable annual expense $E = \frac{4DNw\varepsilon}{x} + \frac{D(t+T)}{x} + 4Dnp$

but $R = 2x/(nc+k)$ ∴ $nc + k = \frac{2x}{R}$ $n = \frac{2x}{cR} - \frac{k}{c}$

$$\therefore E = \frac{4DNw\varepsilon}{x} + \frac{D(t+T)}{x} + \frac{8Dpx}{cR} - \frac{4Dpk}{c}$$

$$\frac{dE}{dx} = -\left\{4DNw\varepsilon \times \frac{1}{x^2} + \frac{D(t+T)}{x^2}\right\} + \frac{8Dp}{cR}$$

for a minimum $\frac{dE}{dx} = 0$ $\frac{8px^2}{cR} = 4Nw\varepsilon + (t+T)$

$$x^2 = \frac{Rc}{8p}\{4Nw\varepsilon + (t+T)\}$$

$$x = \frac{1}{2}\sqrt{\frac{Rc}{2p}\{4Nw\varepsilon + (t+T)\}} \qquad (1)$$

Rc = Number of cir. mil feet in the limiting track

$\frac{Rc}{2p}$ = Number of cir. mil feet in the limiting distance per $ of annual conductor charge

$4Nw\varepsilon$ = cost in $ of the energy wasted annually in the conductors by our transformers

$t+T$ = cost annually of one conductor.

If it is assumed that $w = ax$ i.e. varies directly with the time on one section

Then $E = 4DNax + \frac{D(t+T)}{x} + \frac{8Dpx}{cR} - \frac{4Dpk}{c}$

$$\frac{dE}{dx} = -\frac{D(t+T)}{x^2} + \frac{8Dp}{cR} \quad \therefore \frac{8Dpx^2}{cR} = D(t+T) \text{ for a minimum}$$

$$\therefore x^2 = \frac{cR}{8p}(t+T)$$

$$x = \frac{1}{2}\sqrt{\frac{cR}{2p}(t+T)} \qquad (2)$$

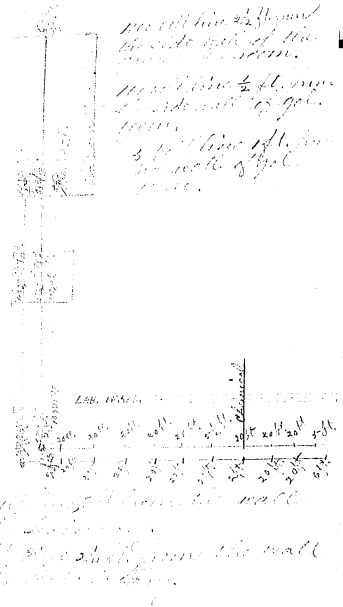
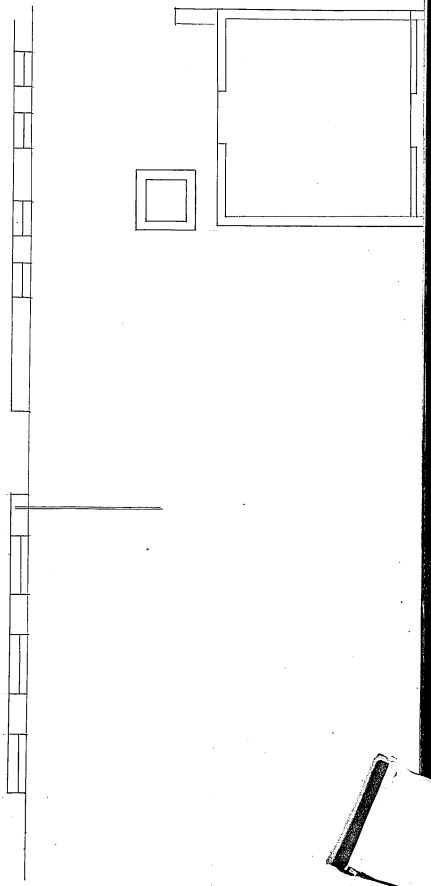
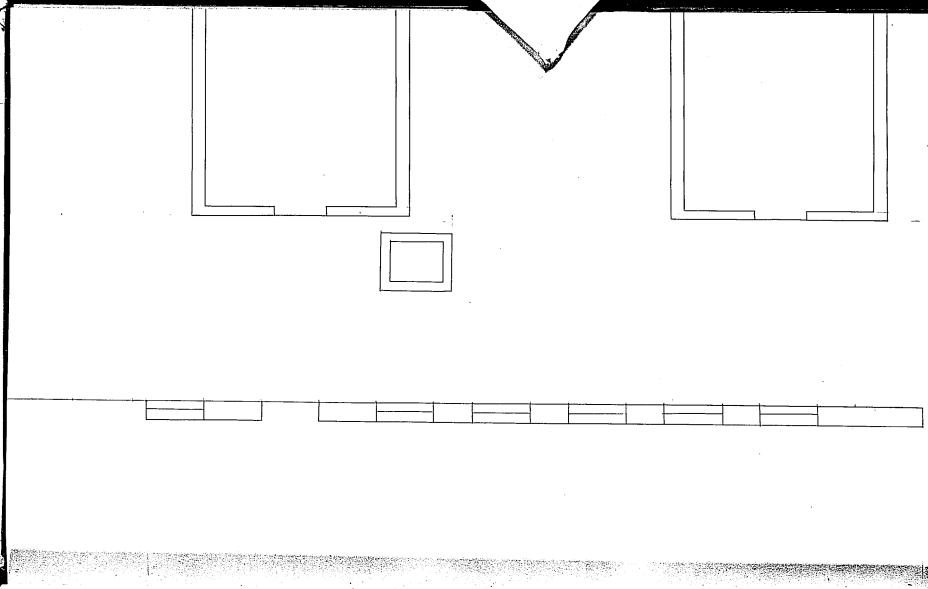


Diagram shewing the arrangement of pipes + tubes in the laboratory.





Phonograph Battery Tests

To compare the relative behavior of cast iron and wrought iron armatures have a cast-iron motor with a 4 cell NaHO battery that had already run one term. It was kept taking off a chip almost the entire period. It failed to take the chip after 50 hours. The battery was cleaned up and refreshed. It was then set to work on a wrought iron motor under similar conditions. It failed after 47½ hours. Another test was made between these two machines with two bichromate cells, regular phonograph chromic acid type. Two cells in series were used. The wrought iron motor ran for 8 hrs and 50 mins. The cast iron 8 hrs and 30 mins. A third test was made in the galvanometer room. Two machines like those above mentioned were used. One cast iron the other wrought iron. Two phonograph 4 cell NaHO batteries were made up one for each, and the motors were driven light. They started at 10:20 o'clock 16th Sept. and stopped at 21 o'clock on the 19th in the case of the cast iron and 6 o'clock on the 21st in the case of the wrought iron armature runs of 76 + 100 hours respectively. The batteries were then recharged and the zincs amalgamated, and the armatures exchanged. The cast iron machine stopped after 27 hours continuous run the resistance being 0.85Ω. The wrought iron machine stopped after a continuous run of 85 hours. Another motor of wrought iron was set running by a battery whose plates had been cut down to half width. It ran continuously for 66 hours, when the int: res: became very high.

Some experiments were next made with 6 cells delivering 4 – 6 amperes of current to represent the behavior of such batteries in connection with a Phelps motor. The ext: res: was 0.5Ω. The current commenced at 2.5 amperes rising after 3 hours to 5.2 (rising subsequently) to 5.7 until after 46 hours when one cell showed a high res: + some chemical decomposition stopped the output of the set. The fluid was milky + smelt of gasolene. The same test was repeated with the same cells but the (milky) amalgamated zinc plates. The current commenced at 5 amperes and continued practically for 60 hours. The int: res: per cell was 0.07Ω (average) and the average E.M.F. 0.67 volt.

Table showing trials of cast iron armatures in running phonographs

No.	Battery	Material of armature	Date & Time of Start		Date & Time of failure		Lifetime	Condition of run.	Speed	Remarks
1	4 cell NaHO	cast iron	16.00	16.IX.89	21.	19.IX.89	75	light	120	
2	. . .	wrought	21.00	16.IX.89	6	21.IX.89	100	"	"	
3	. . .	wrought					85	-	-	Batteries refreshed
4	. . .	cast					27	-	-	
5	. . .	cast malleable	15	15.X.89	4.	19.X.89	88	-	-	
6	. . .	"	15	15.X.89	1.	19.X.89	85	-	-	Gas
7	. . .	cast malleable, half width	8	2.XI.89	2½.	6.XI.89	90	-	-	

Experiments and Data on the
Grounding of the Neutral in 3 wire systems and the
use of the ground in place of the neutral main

September 25th Wednesday.

Employed a ground at the phonograph factory using the hydrant as connection with some 50 feet of #8 copper wire. Made a similar ground at the laboratory by a bolt on the bedplate of the #1 engine.

Res: of mains measured as follows.

+	0.05ω
0	0.07ω
−	0.05ω
	0.07ω

One joining up grounds, and neutral etc. which appeared to make the res: of the ground nil. Joined up both ground and neutral at the phon: factory and used each alternatively at the laboratory. Set the factory motor on one side, making a load of 170 amperes on one side and 90 amperes on the other. Using the ground circuit only as the neutral, the effect of joining up the neutral main in multiple with it only made a change of one volt at the laboratory terminals. Experimentally found that a lead wire was just fused on the neutral main side, which took 2·3 × 2 ÷ 41·95 = 33·8 amperes so that of the 90 amperes travelling along the neutral circuit about 34 close a path of 0·07ω, the difference 46 going via the ground. The effective res: of the ground circuit was thus 0·05ω, or less than the neutral proper.

Inductance Measurements

Two phonoplex induction coil 1·5 cms clearance parallel to each other + on wooden base. Axes 5 cms apart. Length over all 10·5 interflange 9·5. Int: diam: 3·5 Ext: diam: 1·55. Core 1·2 of wire

Coils	Bridge Ratio	Res: of coil	Condenser	KBD	Inductance Quadrant	Inductance Kilometer	Sum Kilometer	Discrepancy	
A	10000/100	6.975	1·414	9.863	0·0986	986	2017		
B	23.5°C	6.992	1·475	10·31	0·1031	1031			
(A) (B)		3·544	1·210	4·299	0·0429	429		195	
A+B.		13·856	1·596	22·12	0·2212	2212			

Testing the effect of mutual inductance at so short a distance repeated test after removing one coil from the base to about 25 cms

Coils	Bridge Ratio	Res: of coil	Condenser	KBD	Inductance Quadrant	Inductance Kilometer	Sum		Joint Ind.	Dis.
A	10000/100	6·892	1·405	9.684	0·0969	968	1986			
B	21.6°C	6·927	1·469	10·180	0·1018	1018				
(A) (B)		3·492	1·344	4·694	0·0469	469		12	496	27
A+B		13·745	1·436	19·740	0·1974	1974				

The phonoplex coil has therefore practically zero res: + 0·1 quadrant

Experiments and data connected with the use of the ground in place of a neutral wire.

On the 26th September, all the system was operated during the evening without a neutral wire. In ~~the~~ each house the center of the installation was connected with the waterpipe system, and the neutral plug removed. Similarly the factory grounded on the hydrant mentioned on the preceding page. The result was quite successful. On removing the neutral connection at the laboratory and grounding the dynamo connection on the bedplate of the engine, no change in adjustment could be observed. The balance was successfully maintained in the houses but owing to the voltmeter being a shorter connection than usual, the voltage in the park was a trifle too low. In Mr. Edison's coachhouse + Mr. Burkis coachhouse, a ground had been omitted and the result proved disastrous to some of the lamps in those buildings. That however was no fault of the principle involved.

Azimuth and Local Time Observations

September 29th Sunday.

Apparent altitude of sun's center 32°.
Time of Observation 14. 49. 40 by watch.
Position of Instrument vertical axis 63" (160 cms) south of end of Equatorial platform midway between rails

Observed magnetic declination 8° W.
With axis of telescope brought to meridian the reading was N 109°. 26'. 0 B 70°. 26'. 00
assume - - - to bisect the center of the pagoda roof of a house near a telegraph pole in a line nearly at right angles to the roof of factory)

A	109°. 28'. 30 B 120°. 26'. 00
	109°. 57'. 30 109°. 57'. 00
Mean	109°. 27'. 37'. 5 109°

Azimuth of pagoda center E

How angle observed 47°. 19'. 20" = 3. 9. 17 (L. M. S.)
Equation of time for noon 9M. 9.48 (M. E.)
Difference for next 24 hrs - 19.4
8 hrs - .6.5
9.55

	9.55
Local Mean time	14. 59. 22
	1. 00
N.Y. Mean time	15. 00. 22
Watch	14. 49. 40
Error –	10. 42

Second measurement.
Apparent altitude of sun's center 29°. 30'
M. Time of Obs. 15. 11. 50. by Watch.
Observed magnetic declination 8° W.
With axis of telescope brought to meridian the reading = A 109°. 30'. 00 B 70°. 29'. 00
assume - - - center of pagoda roof

A	109°. 28'. 30 B 120°. 30'. 00
	50°. 1'. 30 50°. 1'. 00
Mean	50°. 1'. 15" Mag.

How angle observed 52°. 49'. 50" 3. 31. 19

Equation of time	9.55
Local M. Time	15. 21. 24
	1. 00
N.Y. M. Time	15. 22. 24
Watch	11. 00
Error –	10. 24

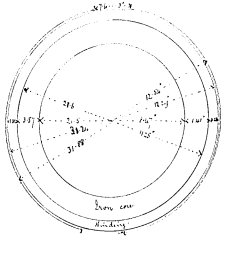
49. 57 375
180. 2. 30
130. 0. 65
But result to det. 50°. 0'. 2"

Clock found to be 1m 23s ahead of watch = 9m. 11s slow

Mathematical Theory of these permeability measurements.

Let l_1 be the length of the standard specimen
- a_1 - - area
- l_2 - - length - - tested
- a_2 - - area - - -

We assume that $l_1 = l_2$ and $a_1 = a_2$ to simplify practice
- L - - length - - large magnet coil
- A - - area - - -
- ρ_1 - - reluctancy - - standard specimen
- ρ_2 - - - - - - - tested
- ρ - - - - - - - large magnet
- ϕ_1 - - flux in l_1 which passes through the circuit on applying the coil L &c
- ϕ_2 - - flux simultaneously in l_2 &c
- ϕ - - permanent flux of magnetic stress in the circuit due to the magnet
- χ_1 - - flux in the air produced by the coil &c
- χ_2 - - - - - - -



Particulars of motor

Peripheral speed	1500 in/per min	3000 ft per min
E.M.F. at terminals when running light	200 volts	

Diameter of ring armature

Int.	21.5	8.47"
Ext.	28.6	11.25"
Thickness	3.97	1.41"
Breadth	17.8	7"
Ext. Depth winding	1.32	0.52"
Clearance	0.32	0.125"

Size of wire on armature 10 B.W.G. 0.134"
Cmils: 18,000

Current at full load 30 amperes each side
C mil per ampere 600 at full load.

Number of layers on armature 3

Turns per block	5 x 3 = 15
Total no. of armature turns	660
Blocks in Commutator	44
Area of armature slot	0.164
Average field	21.33 Gauss
Total calculated flux	2,075,000
Leakage allowed 30%	622,500
Useful flux	1,453,000
Fall of pot. in arm. full load	10 volts
Waste of energy . . .	600 Watts
. field . .	200 .
Total waste at full load	800 .

Field dimensions remain same as those determined for the motor on p. 47.
The field winding is however altered to
15.4 lbs of # 21 B.W.G. wire 0.032" on each limb = 68 lbs in all.
about 20 layers of 150 turns each
Total # turns per limb 3000
. ampere turns per limb 6000
Pot. drop per limb 20 volts per Volt.
Weight of iron on armature 58 lbs p 10 B.W.G.

Problem. To determine the best winding and dimensions for a Bar Motor of 5 kilowatts power at full load, using either an overhead line or subterranean conductor in a conduit.

The motor to be of the Fuller Gramme type, and of about the dimensions shown on page 47. The speed 3000 ft per min = 1500 turns.

The lines to be supplied from the bus-bars of an Solsum Illuminating station of the 3 wire system i.e. at 250 volts pressure. Let us assume at present that this will represent an average pressure of 200 volts at the motors or a general drop in the lines all over the system of 20%.

Then running light the motor must generate an emf. of say 190 volts. The breadth of the armature = 18 cms so that the area generated per sec: = 18 x 1500 = 27000 sq. cms per sec.

At full load let the generated emf be 100 volts then taking the efficiency of the motor @ 85% the power to be absorbed = 5880 and the current will be 59 amperes. Let us try 600 cmils per ampere = 35400 cmils = 0.188" for one wire or 17,000 cmils = 0.134" # 10 wire for two. = 0.134" diam. bars or 0.158" covered. Allowing 0.160" for winding purposes = 0.406 cms and the peripheral of the armature to be 28.6 + 0.4 = 29 cms x π = 91.1 cms ÷ 0.406 = 224 turns say 220. = 44 blocks @ 5 turns each. For half the ring the number of turns = 110 so that the total area swept out per sec: = 2970000 sq. cms ∴ $nf = \frac{190 \times 10^8}{2.97 \times 10^6} = 64 \times 10^2$ with 3 layers (n = 3)

$f = \frac{190 \times 10^8}{3 \cdot 97 \times 10^6} = 2133 = 21.33$ Gauss. The thickness of this winding will be 0.514" x 3 = 0.462" + 0.05" for insulation = 0.512" say 0.52" over all. = 1.32 cms Above this the clearance is ¼ = 0.32 cms making the entire 0.645" = 1.64 cms.

Employing the same dimensions for the field magnet the reluctance of the air space is increased from 0.0027415 to 0.0036624 an increase of 0.000884 bringing the total reluctance up to 0.006988 and the same no. of ampere turns will produce ~~26~~ $\frac{2.275 \times 10^4 \times 5.104}{6.988}$ = 2.075 x 10^4 lines of which if 30% are lost = 0.6225 x 10^4 leaves 1.453 x 10^4 lines for use ÷ 7.16 = 20.3 Gauss.

The res. of the armature will be 4g per turn x $\frac{660}{16}$ = 8090 cms = 265.3 ft equivalent of # 10 wire = 0.159 ohm and the fall of potential through this at full load = 10 volt = 600 Watts.

When delivering	5 Kilowatts =	5000
waste in friction		2000
. armature & field		800
		7800

drop in arm: 10 volts = 190 = 40 amperes current.

With 10 watts per sq. cm, the current may be 2.0 amperes @ 250 volts with all four coils in series the res. must therefore be 200 w. for lamp = 50 w each bobbin. The diam: of the wire is thus

$$-0.02 + \sqrt{0.00014 + 0.00153 \times \sqrt{\frac{2300}{50}}} \times 478$$

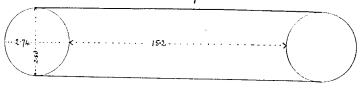
$$0.00014 + 0.01037$$

$$\sqrt{(0.01077)}$$

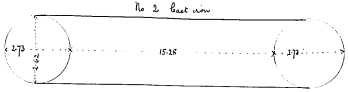
0.104 − 0.02 = 0.0824 cms = 0.033"
= # 21 wire 0.032"
= 15.37 lbs per cm = 61 lbs in all.
= 5000 feet . . = 22,000 ft . .

Mean turn 1.5 ft = 3300 turns = turn 0.05" wide . 150 turns per layer . 22 layers = 1.1"

No 1. Norway iron



No 2 Cast iron



Electro medical Experiment

Having succeeded in forcing lithium by electrical osmose through a bladder, tried the experiment on a man — James Duncan. He kept his hands inserted up to the wrists in a solution of LiCl and NaCl respectively for two hours daily. The current passing through him was 0.004 ampère being as much as he could conveniently stand. At the end of one week after 11 hours total application, tests were applied to his urine collected during that time. By spectrum analysis a solution containing 1 part in 40,000 of LiCl could be detected by a faint red band. No such band was distinguishable from his urine itself, but a condensation of all his urine for the week reduced to the form of sec chloride gave distinct band. The quantity of lithium chloride obtained was 0.22 grammes and this from about 7/8th of the whole week's urine = 0.55 g. from the whole. about 0.09 g. of metallic lithium equivalent to a removal of 2.43 g. urine urea @ 4 per cent.

$$LiCl + C_6H_2H_4N_4O_3 = HCl + C_7H_7LiN_4O_3 — ?$$

Permeability Measurements

Took a welded ring of Norway iron of dimensions shown. The mean diameter = 17.94 and circumference 56.36. The cross section was slightly elliptical, and its area 6.02 sq cms. Overlaid this with one ribbon of rubber tape to a diameter of 2.84 and 2.90 cms respectively. Three layers of #18 B.S. wire 0.0395 (0.100 cm) diam. amount to 0.054" (0.137") with connection wires soldered others were layed on this ring for an angle of 270° ($\frac{3\pi}{2}$). On the first layer were 210 turns on the second 220 and on the outside 212, making 642 in all. Thin rubber paper 0.012" (0.03) was wrapped in a strip round and round between each layer of wire to give a fair surface and a layer of black tape was then added over all. The outside diameter of cross section was then about 4.2.

Took a similar ring of cast iron cast at the phonograph factory of dimensions shown. The mean diameter = 18.01 and circumference 56.5 cms. The cross sectional area was rather more elliptical and it area 2.73 × 2.62 × 0.7854 = 5.62 sq cms. Overlaid with one ribbon of rubber tape and wound with three layers of wound wire just as in the case of no 1. The number of turns in these layers was 212, 212, and 219 making 643 in all. It was wrapped over with black tape so that the two rings resembled each other very closely.

The inductances of the ~~[illegible]~~ cast iron ring was found to be sufficient

No.	Ratio of Bridge	Res. ohms	Permittance	Quadrants	Kilometers	Res. added to coil	Max. Final steady current amperes	Time Const.	H	$\frac{M}{L}$
1	1000/1000	1001.4	0.056	0.0561	560.8	1000	0.00325		0.620	
2		902.17	0.068	0.0611	613.6	900	0.00865		1.231	
3	T.B. 25°C	802.32	0.079	0.0634	633.8	800	0.00705		1.346	
4	Temp of coil 20.5°C	702.32	0.089	0.0625	625.0	700	0.00755		1.499	
5		602.40	0.104	0.0627	626.6	600	0.00560		1.680	
6		502.35	0.127	0.0638	638.0	500	0.01035		1.976	
7		401.35	0.152	0.0615	618.1	400	0.01175		2.243	
8		301.40	0.270	0.0814 ?	813.8 ?	200	0.015640		2.940	
9		201.43	0.319	0.0643	642.7	200	0.02025		3.866	
10		101.50	0.639	0.0649	648.5	100 *	0.03035	0.00065	5.79	
11		91.51	0.704	0.0644	644.2	90				
12		502.35	0.124	0.0622	623.0	500	0.01035			
13		1001.3	0.056	0.0561	560.8	1000	0.00325			

* This critical measurement at which the instrument began to be excessive at 2.11 × 2.2 or 4.29 changes or discharges per sec = 0.23 ÷ 0.00065 = 400 times the time constant.

Meteorological record.

Date 1881	Time	Barometer readings Inches	Corr.	Temp. Corr. to 0° C	Thermometers Max.	Min.	Dry	Wet	Range of temp.	Rainfall 24 hrs	Wind	Weather - Remarks
October	Noon											
1		30.032	76.38	74°	29.906	72°	51°	64°	42°	0.15	NW	Raining
2		30.084	76.43	76°	29.932	74°	46°	63°	60°	—	NW	Fair
3		30.062	76.34	73°	29.939	70°	39°	60°	59°	—	NW	Fine
4		29.912	75.98	64°	29.816	70°	43°	65°	62°	—	NW	Fair
5	"	29.892	75.82	64°	29.676	72°	42°	64°	60°	—	NW	Fine
6		29.760	75.69	61°	29.678	69°	46°	56°	50°	0.19	NW	Overcast
7		29.916	75.99	68°	29.808	67°	36°	63°	60°	—	N	Fine
8		29.836	75.78	74°	29.710	62°	30°	57°	49°	—	N	Overcast
9		29.842	75.82	72°	29.722	60°	38°	49°	42°	—	NE	
10		29.966	76.11	76°	29.854	56°	36°	43°	38°	0.01	NE	Fair
11		29.998	76.17	70°	29.836	57°	39°	50°	46°	0.03	NE	Fair
12		29.934	76.04	73°	29.813	52°	33°	48°	45°	—	NE	Overcast
13	"	29.724	75.50	79°	29.598	47°	38°	48°	42°	0.28	W	Rain "
14		29.628	75.26	75°	29.609	43°	36°	43°	42°	0.38	W	Overcast
15		29.796	75.63	79°	29.617	50°	40°	53°	45°	0.50	W	Fair
16		30.028	76.27	77°	29.843	57°	42°	52°	43°	—	NE	Fine
17		30.000	76.19	76°	29.871	54°	38°	54°	49°	—	NE	Fine
18		29.970	76.12	79°	29.829	58°	48°	54°	47°	—	W	Fine
19		29.934	76.04	71°	29.810	55°	36°	47°	40°	—	W	Fair
20	"	29.850	75.80	75°	29.721	63°	38°	61°	58°	—	W	Fine
21		30.022	76.26	73°	29.828	66°	43°	46°	43°	0.06	W	Overcast
22		30.200	76.71	76°	30.058	49°	40°	48°	42°	—	W	Fine
23		29.964	76.1	79°	29.858	54°	31°	46°	41°	—	NE	Overcast
24		30.124	76.82	85°	30.087	50°	31°	42°	39°	—	E	Fine
25		29.926	75.94	60°	29.760	52°	35°	43°	39°	—	NW	Fair
26		29.936	76.04	60°	29.852	55°	38°	53°	51°	—	NE	Fair
27		29.712	75.40	62°	29.622	54°	36°	52°	50°	0.60	NE	Rain
28		29.600	75.17	75°	29.471	61°	51°	56°	53°	0.32	N	Raining
29		29.916	76.05	72°	29.836	59°	43°	49°	46°	—	W	Fair
30		30.012	76.22	73°	29.884	58°	49°	53°	49°	—	N	Misty, overcast
31		30.054	76.33	70°	29.940	62°	48°	57°	52°	—	NW	Overcast
Nov.	1	30.050	76.32	72°	29.930	56°	45°	56°	54°	0.08	W	Fair
2		29.960	76.10	69°	29.864	56°	43°	54°	50°	—	W	Fair
3		30.064	76.34	72°	29.944	54°	31°	50°	44°	—	NE	"
4		30.064	76.37	60°	29.999	59°	38°	53°	52°	0.17	NE	Overcast
5		30.002	76.19	50°	30.098					—	W	Fair
6		30.122	76.50	46°	30.092					—	W	Fine
7		30.096	76.40	46°	30.097					—	W	"
8		30.010	76.23	51°	29.973	54°	33°	54°	53°	—	W	Overcast
9		29.824	75.74	77°	29.697	52°	42°	50°	49°	1.2	W	Rainy
10		29.820	75.77	76°	29.678	54°	50°	51°	50°	0.06	NE	"
11		29.920	76.00	75°	29.791	56°	38°	53°	50°	0.05	NE	Overcast
12		30.100	76.46	82°	29.950	54°	40°	52°	50°	0.04	E	Fine
13		29.716	75.48	80°	29.572	56°	45°	52°	51°	0.07	NE	Overcast
14		29.750	75.56	82°	29.600	58°	51°	58°	55°	0.80	SW	Fine
15		30.110	76.52	74°	29.989	48°	29°	39°	38°	—	W	Fine
16		30.462	77.37	70°	30.348	60°	26°	34°	32°	—	W	Fine
17		30.208	76.73	63°	30.118	36°	24°	36°	34°	—	NW	Fine
18		30.050	76.33	70°	29.936	45°	33°	40°	39°	—	NE	Overcast
19		29.614	75.22	70°	29.500	49°	39°	46°	46°	1.00	NE	Rainy
20		29.576	75.14	70°	29.469	53°	33°	48°	46°	0.55	W	Overcast
21		29.608	75.22	81°	29.461	49°	39°	48°	47°	—	SW	Fine
22		29.324	74.50	79°	29.181	51°	46°	50°	47°	—	SW	Fair
23		29.750	75.55	80°	29.606	51°	45°	50°	47°	—	NSW	Fair
24		30.010	76.28	58°	29.951	51°	40°	51°	49°	0.39	W	Fair
25		30.066	76.37	75°	29.947	51°	36°	47°	46°	0.20	W	Rainy
26		30.432	77.30	70°	30.318	54°	36°	50°	50°	0.60	W	Fine
27		29.996	76.02	72°	29.926	52°	39°	51°	51°	0.70	NW	Rainy
28		29.650	75.31	76°	29.500	50°	35°	50°	48°	1.28	NW	Dull
29		29.700	75.45	69°	29.589	46°	25°	42°	39°	—	W	Fine
30		30.150	76.57	60°	30.057	40°	25°	33°	32°	—	W	Snow during night
Dec.	1	30.080	76.40	60	29.99 6	38	33	38	36	—	NW	Fine
2		30.000	76.19	67°	29.995	43°	30°	42°	39°	—	W	Fine
3		29.864	75.90	60°	29.780	45°	20°	36°	32°	—	W	Overcast
4		30.306	76.97	65°	30.207	43°	12°	30°	19°	—	W	Snow
5		30.000	76.19	64°	29.944	43°	13°	34°	33°	—	NE	Overcast
6		29.904	75.94	75°	29.771	42°	32°	41°	39°	0.01	E	Fine
7		29.950	76.07	70°	29.836	42°	30°	41°	38°	—	SW	Fine
8		29.966	76.17	75°	29.88	46°	35°	40°	38°	—	SW	Overcast
9		29.988	76.18	72°	29.864	61°	38°	50°	50°	0.55	SW	Rain
10		30.240	76.82	77°	30.133	60°	32°	44°	42°	—	W	Fair
11		29.746	75.60	77°	29.591	52°	40°	45°	43°	—	W	Fine
12		30.070	76.30	75°	29.836	50°	38°	50°	48°	0.26	W	Overcast
13		29.784	76.67	75°	29.632	54°	38°	50°	48°	—	W	Overcast

Permeabilities continued from page 61.

The corresponding measurements with the wrought iron ring were as follow :-

Bridge Ratio	Rec. dev.	Permittance	Quadrants	Kilometers	Rec. added to cent	Final steady recy. current amperes	Lenz Const.	H in the ring.
1000/1000	1001.4	0.031	0.03105	3115	10000	0.00325		0.620
1000/900	902.20	0.040	0.03610	3610	900	0.00645		1.231
	802.30	0.045	0.0361	361.0	800	0.00705		1.346
	702.35	0.050	0.0351	351.2	700	0.00785		1.499
	602.45	0.063	0.0380	379.6	600	0.00880		1.680
	502.50	0.080	0.0420	420.	500	0.01035		1.976
	401.47	0.120	0.0482	481.8	400	0.01175	0.00012	2.243
		unreliable beyond		from	unbearable	of spot.		

The number of turns being 642 spaced over 3/4 lbs of the ring) whose mean circumference = 42.27 cms gives $642 \times 1.75^{\circ} \div 42.27 \times 4\pi = 190.9$ c. in H.

On the dimensions of the sun on the assumption that its density is equal to that of the earth

Commencing with the outermost planet of our system the densities are stated as follows:-

	new Encyc.	
♆	0.935	
♅	0.99	
♄	0.66	
♃	1.21	
♂	5.06	
♁	5.5	
♀	5.06	5.65 by Lockie's Atlas 1887
☿	6.52	6.16 " " " "
☉	1.375	

From this list it is evident that with the exception of Saturn, itself a planet of exceptional form (the density of the moulton increases toward the center. The sun however is a very) notable exception. We have to allow for the sun's heat in estimating his dimensions but assuming that he has a solid nucleus of density equal to that of the earth and that the rest of his bulk is of gaseous raw material then the true dimensions of his solid or liquid nucleus would be determined as follows:-

Let R be the sun apparent radius

r - - - nucleus -

$$\frac{4}{3}\pi R^3 \times 1.375 = \frac{4}{3}\pi r^3 \times 5.5 + \frac{4}{3}\pi (R^3 - r^3) d$$

$$1.375 R^3 = 5.5 r^3 + (R^3 - r^3) d$$

$$r^3 (5.5 - d) = R^3 (1.375 - d).$$

$$r = R \sqrt[3]{\frac{1.375 - d}{5.5 - d}}$$

Here d is the density of the gaseous envelope. Even gold vapor at a very high temperature would have a very low density so we may neglect it entirely for simplicity.

$$\text{Then} \quad r = R \sqrt[3]{0.25}$$

$$= 0.63 R.$$

and if the diameter 2R be 1.375×10^6 kilometers $r = 8.65 \times 10^5$ kilometers and the gaseous layer would therefore be 250,000 kilometers thick.

#1 Front

Planimeter 2·64
5·53
7·43
Mean 2·61 sq. in.

#1 Back

Planimeter 2·36
2·53
2·42
2·36
2·34
Mean 2·40

#3 Front

Planimeter 2·45
4·96
7·45
Mean 2·48

#3 Back Planimeter 2·31
4·62
6·93
Mean 2·34 sq. in.

#4 Front Planimeter 2·80
5·56
8·34
Mean 2·78

#4 Back Planimeter 2·64
5·18
7·78
Mean 2·59

#7 Back Planimeter 2·92
5·85
8·76
Mean 2·92

#7 Front Planimeter 3·17
6·35
9·52
Mean 3·18

Measurements of the activity of the Phonograph Factory Brown Engine

3rd October.

Back constant $2{\cdot}132 \times 10^{-4}$ HP Front Constant $2{\cdot}09 \times 10^{-4}$ HP
$1{\cdot}591 \times 10^{-4}$ K $1{\cdot}552 \times 10^{-4}$ K.

#1. 15·45 o'clock. Pressure $\frac{78+75}{2} = 76{\cdot}5$ 82 revs. per min. 40 opening. Front brass 4·35° Back - 4·17

Front area	2·61 sq. in.	mean coil 0·60°	= 24·6 lg per sq. in.	=	40·9 HP	Kilowatts
Back -	2·40	- - -	0·376° = 23·04 - - -	=	40·3	
					81·2	60·6

#2 15·50 $\frac{80+75}{2} = 77{\cdot}5$ 82 revs.

Front area	2·45 sq. in.	- -	0·543	22·5	=	38·4
Back	2·22		0·532	21·3	=	37·3
						75·7

56·5

#3 16·30 $\frac{75+70}{2} = 72{\cdot}5$ 84 revs.

Front	2·48		0·570	22·5	=	38·4
Back	2·29		0·549	22·0	=	39·0
						78·4

57·0

#4 ~~16·32~~ $\frac{73+70+68+65}{4} = 69$ 80 revs.

Front	2·78		0·639	23·6	=	42·6
Back	2·59		0·621	21·8	=	42·3
						84·9

63·4

#5 17·00 $\frac{80+76}{2} = 78$ 81 revs.

Front	3·00		0·690	27·6	=	46·5
Back	2·74		0·657	26·3	=	45·4
						91·9

68·6

#6 17·15 $\frac{62+59}{2} = 60{\cdot}5$ 80 revs.

Front	3·12		0·717	28·7	=	47·8
Back	2·89		0·693	27·7	=	47·2
						95·0

70·9

#7 17·28 $\frac{65+60}{2} = 62{\cdot}5$ 80 -

Front	3·08		0·708	28·3	=	47·1
Back	2·95		0·707	28·3	=	48·3
						95·4

71·2

Back constant	HP	K	Front constant	HP	K
@ 75 revs.	1·599	1·193	@ 75 revs	1·560	1·164
76 -	1·620	1·209	76	1·580	1·180
77	1·642	1·225	77	1·601	1·195
78	1·663	1·241	78	1·622	1·211
79	1·684	1·257	79	1·643	1·226
80	1·705	1·273	80	1·664	1·241
81	1·727	1·289	81	1·686	1·257
82	1·749	1·305	82	1·705	1·273
83	1·770	1·320	83	1·726	1·288
84	1·791	1·336	84	1·747	1·304
85	1·812	1·352	85	1·768	1·320

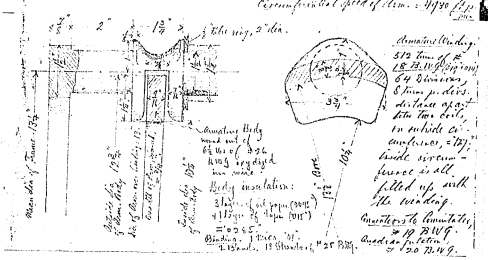
Between #3 + #4 the heat was set at work for the cylinder. This increased the current on the motor from 50 to 130 amperes = 50 × 105 = 5250 Watts = 5·25 @ 88% eff = 6·48 Kilowatts and the observed increase = 6·4.

Between #4 + #6 a number of lamps were turned on

Remounted the suspension of the Ballistic Galvanometer on the 28th September, the fibre having broken. This fibre has borne the weight of the suspended system nearly two years and the weight is 2·91 grammes. Unable to obtain any fibres from the original stock capable of lifting this weight so had recourse to a cocoon. The latter gave a good fibre tested with 3 grammes weight.

The res. of the galvanometer was 5238 ω apparent the T.B. being 24·5°C and that of the coil 19°C. The ratio coil/gal and the ind. coil/gal. 0·360 + so that the inductance of the apparatus all four coils in series = 1·886 quadrants.

½ HP. Octopolar Motor. For the Edison Dynamo. 13 Volts. 30 Amps 1400 R.P.M.
Circumferential Speed of Arm. = 4930 ft.p.m.



(exp. cotton wound (.002 + .007))

Magnet Winding: ⅞ lb of #21 B.W.G. on each of the 16 cores, making the total weight of magnet wire = 2 lbs.

Magnets connected in two parallel rows of 8.

85 turns of wire on each core. Resistance of each core = .407 ohm.

Total Magnet Resistance = 1.627 ohm.

Current in Field circuit = 2.3055 Amperes.

Magnetizing Power of each Magnet = 219 Ampere turns.

Average Field, 650 lines of force p. square inch of pole surface.

Armature – Resistance = .0128 ohm.

Electrical Efficiency = 85%.

Weight – 75 lbs. Watts p. lb = 5.

Orange N.J., June 20, 89.

A. E. Kennelly.

Calculations for the best arrangement of Lalande Battery to suit the Motor designed by Wiener for Mr Edison's tricycle.

The motor is designed for 7·5 volts. and 50 ampères. making 375 Watts. It is called a ½ HP motor and if 50 ampères be its full load current it will do most work when 15 volts are applied to its terminals. To allow for fall of potential in the battery about 20 volts ought to be applied but we will commence with 15. ÷ 0·66 = 22·5 say 23 cells of the Phonograph type. of plate which average 0·66 w. and 0·025 w paralell. The res: of 23 cells would be 0·6 w. the res: of the armature 0·0128 w Then

$$50 = \frac{15 - 7.5}{\frac{0.6}{x} + 0.0128\,w} = \frac{7.5\,x}{0.6 + 0.0128\,x}$$

$x = 5$ approximately).

So that 5 rows of 23 cells each would supply 50 ampères = 10 ampères per row. The Total energy would be 750 Watts, the work in the battery 300, in the armature 325 and the balance 417·5 would be available for use. The current in each cell would be 10 ampères, rather a heavy one.

Keeping the number of cells constant — 115 — or say 120, They might be connected in six rows of 20 each

The E.M.F. would be 13·3 volts the res: per row of 20 · 0·5w

$$13.3 - 7.5 \Big/ \frac{0.5}{6} + 0.013 = 5.8 \Big/ 0.096 = 60 \text{ ampères.}$$

Drop in battery 60 × 0·083 = 5 volts = 8·3 on terminals of motor.

Energy wasted in battery 300 Watts, in armature 47 leaving out of 798 453 for use. but 10 ampères per cell + 60 in armature

With 4 rows of 30 cells each emf. = 20 res: per row 7·5w.

$$20 - 7.5 \Big/ \frac{0.5}{4} + 0.013 = 12.5 \Big/ 0.201 = 62.2 \text{ ampères.} = 15\cdot \text{ per cell}$$

The best arrangement is evidently 5 rows of 23 cells each.

Say 20 each = 13·3 volts. res: per row 0·5w

$$13.3 - 7.5 \Big/ \frac{0.5}{3} + 0.013 = 5.8 \Big/ 0.113 = 51.3 \text{ ampères.}$$

drop in battery 5·13 = 8·17 volts left on terminals of motor.

Total energy 13·3 × 51·3 = 684 Watts in battery 262 leaving 422 available

Say 18 each = 12 volts res: per row 0·45 w

$$12 - 7.5 \Big/ \frac{0.45}{5} + 0.013 = 4.5 \Big/ 0.103 = 43.7 \text{ ampères.}$$

drop in battery 43·7 × 0·09 = 3·93 volts = 8·07 volts on motor

Energy wasted in battery 0·09 × 43·7² = 172 total energy 524

" " armature = 31 available. 203 / 321

The magnet will take 20 leaving 300 Watts.

The safe limit will thus be 5 rows of 18 cells each.

Street Car Electrical Railroad data

If cars run every quarter of an hour each way on a double track at the average rate of 5.5 miles (5250 ft) per hr = 29,000 ft per hour = 7250 feet apart, and if every ten minutes 4830 feet apart.

On the Orange Railroad of the routes crossing each other (from Washington St. and in Valley Road to the limit of Prospect St. in Orange and from Roseville avenue to Fremont avenue there would be some 31 transformers 600 feet apart = 18600 feet of road = 37200 feet of track and 9 cars would be running. Each car might absorb on the average 5 kilowatts and @ 60% efficiency 12.6 amperes from the main circuit. There would then be 114 amperes actively employed and about 20 transformers would be idle each absorbing 2 amperes say = 40 amperes making a total of 154 amperes which with leakage might be 160 amperes 160 amperes @ 1200 volts 192,000 Watts.

If cars run every 5 minutes they will be 2400 feet apart and 16 would be on the track = 200 amperes actively employed and about 16 transformers idle = 32 amperes making a total of 232 amperes which with leakage might reach 240.

One main feeder running south might supply the transformer mains at about Central Ave. Bonus being 7000 feet in length. It might be assumed to supply transformers 24 to 31 = 11 transformers half of which are on full load = 69.3 amperes and the other half take 2 amperes each = 11 amperes = 80. amperes to be carried 7000 feet and if 1100 volts be applied at transformer terminals 1150 volts might be allowed for supply at transformer mains = 50 volt drop in mains. The dimensions of the wire are now to be determined.

If r be the res. per foot of the wire 800 = the drop per foot and 560,000 = d the drop in the whole feeder.

for d = 50	$r = \frac{1}{11200}$	8.9×10^{-5}	0.0000089	0.346
= 100	$r = \frac{1}{5600}$	1.78×10^{-4}	0.0000178	0.245
= 150	$r = \frac{1}{3730}$	2.68×10^{-4}	0.0000268	0.200
= 200	$r = \frac{1}{2800}$	3.57×10^{-4}	0.000357	0.173 about #7 B&S.

So that on this feeder if the ground be used as a return circuit #7 wire would carry the load if supplied at the station somewhere near Park Ave. & Park Place with 1350 volts.

A second feeder about 1500 feet long would supply transformers 1 2 3 4 5 6 14 15 16 17 18 19 & 20 = 12 in all the current would be 75.6 + 12 = 87.6 amperes say 90. d = 1350000

d = 50	$r = \frac{1}{2700}$	3.7×10^{-4}	0.000370	0.158 #8
= 100	$r = \frac{1}{1350}$	7.41×10^{-4}	0.000741	0.122 #11 B&S.
= 150	$r = \frac{1}{900}$	1.11×10^{-3}	0.00111	0.095
= 200	$r = \frac{1}{675}$	1.4814×10^{-3}	0.001148	0.079 about #13 B&S.

As this is much too small a wire we can take a #8 wire and allow a heavier drop in the mains over this section of the line.

A third feeder about 4500 feet would join Dodd St about Glenwood ave. and supply transformers 6 to 13 = 8 = 60 amperes

d = 290,000.

for 50 volt $r = \frac{1}{5400} = 1.852 \times 10^{-4} = 0.000185$ 0.234

100 " $r = \frac{1}{2700} = 3.704 \times 10^{-4} = 0.000370$ 0.173 #7 B&W.

150 " $r = \frac{1}{1800} = 5.56 \times 10^{-4} = 0.000556$ 0.141 #9.

200 " $r = \frac{1}{1350} = 7.41 \times 10^{-4} = 0.000741$ 0.109

As 100 volts drop in the feeder answers very well for the Northern and central line the southern feeder may be divided into two, one to feed transformer 27–31 5 at a point close to Highland Ave. station and the other the remaining 20 – 27 = 8. The current on the former would be 31.5 + 5 = 36.5 amperes its length 8700 feet that on the latter 60 amperes 5000 feet joining at Henry St.

for the former d = 317,550.

for 100 volt $r = \frac{1}{3175} = 3.146 \times 10^{-4}$ 0.000314 0.173 #7 B&W.

for the latter d = 300,000

for 100 volt $r = \frac{1}{3000} = 3.33 \times 10^{-4} = 0.000333$ 0.173 #7 B.W.G.

So that we have south #1 8700 feet of #7 B.W.G.

#2 5000 - - - -

centre #3 1500 - - 11 - -

north #4 4500 - - 7 - -

giving a total of 147,000 feet of #7 B.W.G. and 1500 feet of #11 B.W.G. using the ground as a return 1450 lbs of #7 and 100 lbs #11.

The mains have now to be determined

For the south #1 the center of distribution will be 1000 feet 18 amperes, and d = 18,000 for 50 volt $r = \frac{1}{360}$ $2.78 \times 10^{-3} = 0.00278$ 0.070" diam = #18 B.W.G.

For south #2 the center of distribution will be about 1000 feet 30 amperes d = 30,000 for 50 volt $r = \frac{1}{6000} = 1.67 \times 10^{-3} = 0.00167$ = 0.059 #18 B.W.G.

For central #3 the center of distribution will be about 1500 feet south and 5% transformers and about 2000 feet north 7% transformers (36.5 and 51 amperes respectively). This will mean

S. d = 54,700 r for 50 volt $r = \frac{1}{10904} = 9.0 \times 10^{-4} = 0.00009$ = 0.109" #12 B.W.G.

N d = 102,000 - 50 r $\frac{1}{20410} = 5.0 \times 10^{-4} = 0.0005$ = 0.141" #9 B.W.G.

We should thus have 18600 feet of #9 B.W.G. weighing 1200 lbs.

Test of faulty one milling pick off magnet

Res. of circuit 11.63 ω lead 2.55 magnet 9.28

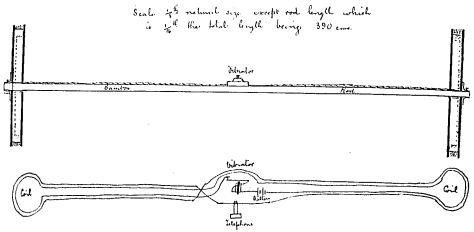
added 4 bulb 100% 100% ω

Distance of ground 1.5050 from heating table

lead 1.175

.33 ω

.33 ÷ 0.0043 = $\frac{330}{4.3}$ = 80 feet.



Measurements of the Inductance in the 12-foot pole induction balance for having iron ore.

4 layers each of about 105 cms circumference (mean) of #24 silk covered wire 0.022" (0.055 cm) were wound on the thin wooden rod shown in section. These layers were doubly wound with 15 turns each = 30 turns in all, or 6300 cms in each circuit. The following measurements were made with the coils.

No.	Ratio Coil Bridge	Res. Ohms	Condensers	Diff. Inductances Gradiants	Diff. Inductances Kilometers	Mutuals Gradiants	Mutuals Kilometers	Differential Mean for Kilometer
1	1000/100 A	7.520	0.665	0.0050	50.02			
2	TB 25.5° B	7.290	0.685	0.0050	49.92			
3	B+A	7.300	0.700	0.0051	51.10	-	0.58	0.4455
4	B-A	7.300	0.675	0.00449	49.21	-	0.33	

Obtained a good balance with the two coil by altering the winding. On taking the apparatus out to the ore pile. It was found that exciting by 3 Grenell Bunsen cells powerful effect could be obtained with big iron pipes at the ore when one bobbin was close up to it but the limit of intensity was very narrow and two feet away it was imperceptible.

Borsilate Tests

Received from Mr Hutchinson on the 3rd October several samples of borsilate for further tests.

Sp: gr: 1.4438 @ 22° C.

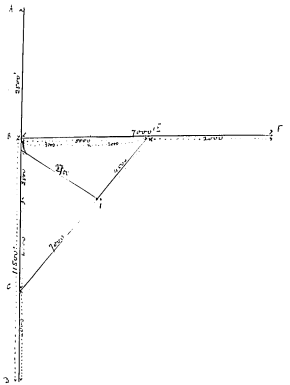
1 piece was exposed to rain + sun for two days in the open air and then placed in water for 5 days more. It showed slight softening and it was observed to be practically o.k.

#2 piece placed on boiler and exposed to temp. of 150°F for seven days. Behavior perfect

#3 piece was used as a lamp socket for 8 days + kept in a box at about 210° F. (100°C) no bad results observed

#4 piece buried about 4" in moist earth, under gutter. This piece showed mouldy condition and was very brittle.

# 5	specimen immersed in	$C_{10}H_{16}$ turpentine		not attacked
# 6	- - -	conc. C_4H_6O	not attacked cold but temporarily softened on heating	
# 7	- - -	cold water H_2O	- - -	on boiling temporarily softened
# 8	- - -	$NaHO$ 1.2 sp. g.	became red paste and dissolved in 45 minutes	
# 9	- - -	H_2SO_4 50%	-	slightly softened. Dissolved with decomposition on boiling
# 10	- - -	conc. HNO_3	attacked cold + totally dissolved on boiling	
# 11	- - -	$C_6H_8O_7$	- -	-
# 12	- - -	NH_4HO	- -	-
# 13	- - -	sol. $NaCl$ 20%	after 20 hours superficially softened	
# 14	- - -	weak sol. $NaCl$ to imitate sea water	slightly softened but still quite serviceable after 5 days	



Street Car Railroad Data
on 250 volt conduit system.

Cars assumed to run every 5 mins, and consequently to be 2400 feet apart, at average speed of 5.5 miles per hour. Each car to be supplied with 5 Kilowatts on the average. Taking the same Orange district there would be 21000 feet of distance + 42000 feet of track.

The motors will be wound for 220 volt terminal P.D. and if worked at an efficiency of 75% on average load, their e.m.f. will be 165 volts. To absorb 5 kilowatts they will take 30.3 amperes, including magnetizing current say 32 amperes. There will be 6 cars on the eastern route, two on the northern, 10 on the southern. The eastern section will thus take 192 amperes, the northern 64, the southern 320. Total 576 - Here Kilowatts. On this basis the drop between station and car on feeders and mains would be 20 volts = 12.%. The feeders would be Edison tubes and the mains would be conduits. A drop of 20 volts might be permitted in the feeders and 10 volts in the mains.

The southern feeder as on page 66 would be 7000 feet long
" central " " " " " 2700 " "
" northern " " " " " " 4500 " "

On the main AD there would be ~~4 x 7.2~~ = 138 amperes at 2000 feet distance ∴ $\frac{276000}{2} \times r = 10$ ∴ $r = \frac{10}{138000} = \frac{1}{13800} \times 10^{-4} = 1000 \times 7245$ = 15,000 cmil. 150,000 cmil on each track - #150 tube conductor.

Feeder 1C will carry 276 amperes say 280 and being 7000 feet in length $280 \times 7000 \times r = 20$ ∴ $r = \frac{2}{280 \times 7000} = \frac{1}{980000}$ 1000000 cmil #1000 tube.

Feeder 1B will carry 8.5 x 7.2 = 262 amperes and being 2700 feet in length can also be #360 tube.

Feeder 1E will carry 129 amperes and being 4500 feet in length can also ~~being~~ #260 tube.

~~There will there be 14,200 feet of #20 feeder = 284,000,000 cmil feet.~~
~~= 862 say 900 lbs in all.~~

~~There will also be 42,000 " " #30 main = 1,260,000,000 cmil feet~~
~~= 3780 say 4000 lbs in all.~~

There will there be 40,000 ft of #150 conductor = 6000,000,000 cmil ft
= 18000 lbs.

7000 " " 1000 " = 7000 million cmil ft
= 21000 lbs.

2700 " " 360 " = 972 " "
= 3000 lbs.

4500 " " 260 " = 1170 million cmil ft
= 3500 lbs

Total 45,500 lbs copper.

Comparison of the Transformer and Direct Systems of Street Car Railroad Operation on the specimen Orange Route.

Transformer

Plant. In addition to Cars motors + track.
Central Station

Dynamos to supply 280 a @ 1250v
Energy 300 Kilowatts (400 H) supplied
Engine developing 333 Kilowatts 446 H. P. @ 20%
Time 18 hrs daily 6000 Kwhrs 8000 H hrs @ 25¢
= $1200.00 daily = $73,000 annually, — $73,000

31 Transformers @ $1000 = $31,000
interest + depreciation @ 10%. — 3,100

Lines Feeder 14,700 ft. # 7 B&S.
2000 " # 10 "
= 16.00 lbs of copper @ 25¢ $4.00
Int + depreciation 10% — 40

Mains in Primary system
18,600 feet of # 9 B&S. 120 lbs copper
@ 25 ¢ = 300 $. int — 30

Secondary mains second to track
19000 ft @ $1.20 per ft. $23,000
int + depreciation 15% — 3,450.

Power + conductors annually $79,620

Energy Account.

	Watts
18 cars averaging 5 kwh each	90,000
Loss in motor armature	15,000
" " rails	5,000
" " transformer secondary	18,000
" " " primary	22,000
" " friction in transformers	60,000
" " primary main feeder	15,000
	300,000
" " dynamos + shafting	32,000
Energy developed at engine shafts	333,000

nett efficiency of system 27%

Direct.

Plant In addition to Cars, motors, + track.
Central Station

Dynamos to supply 580 amp @ 250 v.
Energy 145 Kilowatts 193 H. supplied
Engine developing 192 Kw. 215 H @ 30%
Time 16 hrs daily 2900 Kwhr. 3870 H hrs @ 25¢
= $ 97.00 daily = $35,400 annually — $35,400

40,000 ft. of # 150 E.G. conduit conductor
@ $1.75 per ft = $70,000
Int. + dep. @ 15% — 10,500

7000 ft of # 1000 E.G. feeder
= 3 lbs copper per ft @ 25¢
= $525.00 10% — 5,250

2700 ft of # 360 E.G. feeder
1.1 lbs copper per ft @ 25¢
$150 — 750

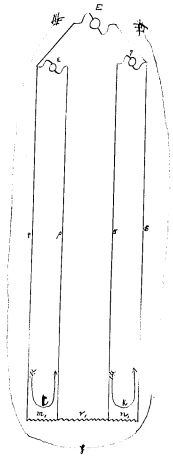
4500 ft of # 240 E.G. feeder
0.8 lbs copper per ft @ 25¢
$900 — 900

Power + conductors annually $52,800

Energy account

	Watts
18 cars averaging 5 kwh each	90,000
Loss in armatures	30,000
" " magnets	5,000
" " conduit	5,000
" " feeder.	12,500
	142,500
" " dynamos + shafting	16,000
Energy developed at engine shafts	161,000

nett efficiency of system 56%



Mathematical Examination of System about to be patented by Mr Edison

October 15th 1889.

Let E be the e.m.f at terminals of main supply
" ε " - - - - - - left "
" η " - - - - - - right "
" ρ - - common pressure at feeder extremities.
" m - - number of lamps on left hand
" n - - - - - - right -
" r - - - - - in centre.
" γ - - main current from E
" ε - - left hand circulation through c
" κ - - right - - - η

Required for a given system of feeder of resistances r ρ σ and s the emf necessary for E ε and η when m n and r are varied in any manner, the resistance of any lamp being l.

Also let $m_1 = \frac{l}{m}$ $n_1 = \frac{l}{n}$ $r_1 = \frac{l}{r}$

Then
$$E = (\gamma+c)(m_1+r) + \gamma r_1 + (\gamma+k)(n_1+s) = \quad (1)$$
$$\varepsilon = (\gamma+c)(m_1+r) + c\rho \quad (2)$$
$$\eta = (\gamma+k)(n_1+s) + k\sigma \quad (3)$$

$$\therefore \quad E = (\gamma+c)r + (\gamma+k)s + 3\rho \quad (4)$$
$$\varepsilon = (\gamma+c)r + c\rho + \rho \quad (5)$$
$$\eta = (\gamma+k)s + k\sigma + \rho \quad (6)$$

Also if $il = \rho$ then $c + \gamma = \frac{mi}{l}$ $\gamma = ri$ $\gamma + k = ni$ (7)

$$E = mir + nis + 3\rho \quad (8)$$
$$\varepsilon = m_1 ir + (m_1 - r_1)i\rho + \rho \quad (9)$$
$$\eta = n_1 is + (n_1 - r_1)i\sigma + \rho \quad (10)$$

Suppose $m = n = r$ (10a)

$$E = m_1 ir + m_1 is + 3\rho \quad (11)$$
$$\varepsilon = mir + \rho \quad (12)$$
$$\eta = mis + \rho \quad \therefore E = \eta = \tfrac{2}{3}(r+s+\rho)(13)$$

Suppose $m_1 = 0$ $\therefore m_1 = \infty$

$$E = nis + 3\rho$$
$$\varepsilon = -rip + \rho$$
$$\eta = nis + (n-r)i\sigma + \rho$$

Suppose $r = 0$

$$E = nis + 3\rho$$
$$\varepsilon = \rho$$
$$\eta = nis + ni\sigma + \rho$$

And for any given values of m and r there correspond only one definite set of values for E ε and η.

Suppose m = a large number in great excess

$$\left.\begin{aligned} E &= Mir + nis + 3\rho \\ \varepsilon &= Mir + (M-r)i\rho + \rho \\ \eta &= Mis + (n-r)i\sigma + \rho \end{aligned}\right\} \varepsilon > \rho$$

Suppose r = N a large number

$$\varepsilon = m(r+\rho) - N\rho + \rho \qquad \eta = ni(s+\sigma) - Ni\sigma + \rho$$

If $N\rho > m(r+\rho)$ $\varepsilon < \rho$. + If $N\sigma > n(s+\sigma)$ $\eta < \rho$

So that ε will be $< \rho$ when $\frac{r}{m} > \left(1 + \frac{\rho}{r}\right)$

η - - $< \rho$ - $\frac{r}{n} > \left(1 + \frac{\sigma}{s}\right)$

General formula for determining the dimensions of power mains.

If l be the length of the conductor (to and fro)
" ρ " " res: per unit volume (resistivity) ohms
" a " " area
" d " " diameter
" v " " pressure of supply (volts)
" δ " " of drop in the mains
" ε " " energy to be supplied

Then the pressure of arrival is $v\left(\frac{100-d}{100}\right)$
" current is $\frac{\varepsilon}{v}\left(\frac{100}{100-d}\right)$

$$\therefore \quad \frac{vd}{100} = \frac{\varepsilon}{v}\left(\frac{100}{100-d}\right)\frac{4l\rho}{\pi d^2} = \frac{\varepsilon}{v}\left(\frac{100}{100-d}\right)\frac{l\rho}{a}$$

$$a = \frac{\varepsilon}{v^2}\left(\frac{10{,}000}{100-d}\right)\frac{l\rho}{d} \qquad (1)$$

If ρ be taken as $1{\cdot}7 \times 10^{-6}$
then a will be in sq: cms.

Or if ρ be taken as 10 and l be given in feet
a will be in circular mils

$$\therefore \text{cmils} = \frac{100{,}000\ \varepsilon\ l}{v^2 d\ (100-d)}$$

$$\text{cmils} = \frac{10^8\ \varepsilon\ l}{v^2 d\ (100-d)} \quad \text{where } \varepsilon \text{ is in h.p. watts} \qquad (2)$$

Since a cmil foot weighs $3{\cdot}015 \times 10^{-6}$ lbs.

$$\text{weight per foot } w = \frac{3{\cdot}015\ \varepsilon l \times 10^{-2}}{v^2 d\ (100-d)}. \qquad (3)$$

and total weight W = $\frac{3{\cdot}015\ \varepsilon\ l^2 \times 10^{-2}}{v^2 d\ (100-d)}$ lbs. (4)

$$= \frac{13{\cdot}46\ \varepsilon\ l^2 \times 10^{-4}}{v^2 d\ (100-d)} \text{ tons} \qquad (5)$$

Calculation of the dimensions of conductor required to transmit power from Niagara to Buffalo. a distance of seventeen miles

89,760 feet (say) 90,000 feet (1) (using ground return)

Let the P.D. at dynamo terminals = 6000 volts. (v)
" drop in this line be d %.
Then if there be negligible leakage
" let ε be the power to be transmitted (watts)
" c " " current in the line (amperes)
" δ " " drop in the line. (volts)
" k " " conductance of 1 cmil ft. (mhos)
" n " " no: of cmils.

Then $(v-\delta)c = \varepsilon$

$$\therefore c = \frac{100\varepsilon}{100v - dv} = \frac{\varepsilon}{v}\left(\frac{100}{100-d}\right)$$

$$\delta = cr = c\left(\frac{1}{nk}\right) = \frac{cl}{nk} \quad \therefore$$

$$\delta = \frac{dv}{100} = \frac{cl}{nk}$$

$$\therefore n = \frac{100cl}{kdv}$$

$$= \frac{100\,l}{d\,kv^2}\frac{\varepsilon}{}\left(\frac{100}{100-d}\right) = \frac{10{,}000\ l\varepsilon}{d\,(100-d)\,kv^2}$$

Let $d = 15$ $v = 6000$ $l = 90{,}000$ $\varepsilon = 150{,}000\,\text{HP} = 112{,}000{,}000$ $k = 0{\cdot}1$

$$= \frac{1{\cdot}0 \times 10^4 \times 9{\cdot}0 \times 10^4 \times 1{\cdot}12 \times 10^8 \times 1{\cdot}0 \times 10^2}{15 \times 10^1 \times 1{\cdot}0 \times 10^{-1} \times 6{\cdot}0 \times 6{\cdot}0 \times 10^7 \times 5{\cdot}5 \times 10^1}$$

$$= \frac{10{\cdot}08 \times 10^{14}}{459 \times 10^7} = \frac{10{\cdot}08 \times 10^{14}}{4{\cdot}59 \times 10^9} = 2{\cdot}20 \times 10^7$$

$= 22$ million cmils.

For 150,000 HP = 112,000 watts = 22,000 amperes.
" 20,000 HP = 15,000 " = 3000 " approx.

$$= \frac{40 \times 10^4 \times 9{\cdot}0 \times 10^4 \times 1{\cdot}5 \times 10^2}{4{\cdot}59 \times 10^9} = \frac{13{\cdot}5 \times 10^{14}}{4{\cdot}59 \times 10^9} = 2{\cdot}94 \times 10^6.$$

36·75 #8 B.W.G. wire makes 1 million c. mils.
110 #3 " " " 3 " " "

$2{\cdot}94 \times 10^6 \times 9{\cdot}0 \times 10^4 = 26{\cdot}46 \times 10^{10} = 2{\cdot}646 \times 10^{11} \times 3{\cdot}015 \times 10^{-6}$ lbs

$= 7{\cdot}978 \times 10^5$ lbs
@ 20 c per lb
$= 159{,}56 \times 10^2$ \$
$= \$159{,}560$

Electrolytic determination of the Ohach Ring Constant. after removing suspension on a single cocoon fibre. 14. X. 82.
The weight of the suspension (needle, weight, stem + points) 2·34 g.

Silver plating in 25% solution $AgNO_3$ almost neutral.

Weight before heat (1) 15·6110
(2) " 19·2275

Current of about 2 amperes passed for just 300 seconds
Deflection 0·1400, 0·399, 0·1400 } 0·3997

Weight after heat (1) 16·2850
(2) 17·5450

$+ 0{\cdot}6740 \quad - 0{\cdot}6825$

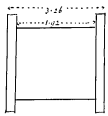
$0{\cdot}6782$

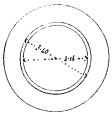
$0{\cdot}00111182 \times 300 = 0{\cdot}33546$

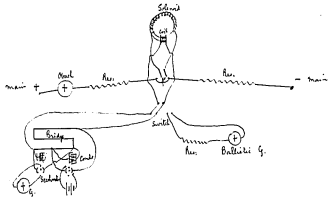
$= 2{\cdot}022$ amperes

$= 0{\cdot}1977$ per ampere. $\left(\frac{1}{5{\cdot}058}\right)$

Galvanometer gives equal deflections on each side within limits of obs.







$56.36 \times \frac{2}{3} = 37.57$ mm length of coil

$642 \div 37.57 = 17.09$

$17.09 \times 1.257 = 21.48$

Permeability Measurements.

October 16th & 17th

Set up the Ballistic galvanometer and took two series of permeability measurements with the Norway iron ring described on page 61. The first series could not be directly interpreted owing to the inertive condition of the galvo. subsequently brought to notice. The magnetic system was found to have like poles. The suspension was then taken down + remagnetized. Indirectly however from the results of the second series, the first are obtainable.

A small wooden reel of hard wood made in two halves was placed on the iron ring in the center of the space unoccupied by the winding, and it was then wound with fine silk covered wire. On the first layer there were 51 turns, on the second 52, on the third 53, on the fourth 52, on the fifth 51 and on the outermost 50 making 309 turns in all, tissue paper being laid between each layer. This wire was #30 S.W.G. 0.012" diam. covered to 0.014".

The following are the results of series #1.

Obs. No.	Deflection of Normal galvo	Amperes	Deflection Throw on Ballistic at Shunt	Res. of Ballistic at Shunt	a	φ	Σ	H	μ	Res. coil alone	Resistivity for volume	Induction K.Kilomaxwells
1	0 Switch									13.52	0.225	30.42
2	0.060	0.054	29.5	5300			1310	1.16		13.55	0.220	29.81
3	0.094	0.084	65.5	"			2900	1.81		"	"	29.81
4	0.191	0.171	141	"			6250	3.67		13.55	0.200	27.10
5	0.340	0.304	203	"			8990	6.53		"	"	27.10
6	Shunts 0.212	1.083	311	"			13770	23.26		13.57	0.155	21.03
			119.4	13700			13670			—	—	21.03
7	0.453	2.292	736	"			15570	49.24		13.57	(0.135) (1.50)	18.32 20.35
8	0.588	2.974	1411.5	"			16200	63.89		13.67	1.390	19.00
9	0.810	4.097	1145	"			16600	88.00		13.67	1.270	17.36
10	1.223	6.185	1148.5	"			17000	132.9		13.82	1.120	15.48
11	2.04	10.32	1547	"			17110	221.6		13.87	1.030	14.29
12	1.195	6.043	1148.3	"			16980	129.8		14.56	1.800	16.02
13	0.755	3.919	1144	"			16490	82.04		14.65	1.200	17.58
14	0.363	1.936	126.2	"			15600	39.44		14.82	1.460	21.64
15	0.200	1.011	122.3	"			14200	24.71		14.77	1.780	26.29
16	1.157	0.794	114.2	"			13070	24.06		14.53	1.852	26.88
17	0.109	0.506	97.5	"			11380	10.87		14.32	2.180	31.21
18	0.313	0.280	257	5300			9260	6.015		14.26	2.280	32.51
19	0.195	0.175	209	"			6960	3.76		14.15	2.80	39.61
20	0.100	0.086	155	"			3370	1.85		—	—	39.61
21	0.050	0.043	76	"			12.00	.975		14.00	2.75	38.55

* Bridge ratio changed from 1000/1000 to 100/100.

Temp.: Ballistic Galvo 74°F 23.3°C T.B. 27.2°C.

There is very great uncertainty in taking the value of a from the ballistic throw with Σ less than 7000 for with a needle whose period is 12 seconds, the discharge continues at diminishing rate during several periods which H is below 14. Above these values the induction becomes more decided, and rapid.

$$1.6285 \times 10^{9} \times 1.0 \times 10^{-15} = 10\mu \text{ dis}$$

$$(\phi) \quad \therefore \quad 1.0 \times 10^{-7} = 72.8 -$$

$$1.511 \times 10^{-7} = \frac{3.09\ \varphi \times 10^{2}}{3.03 \times 10^{9}} = \frac{1}{0.9802 \times 10^{n}}$$

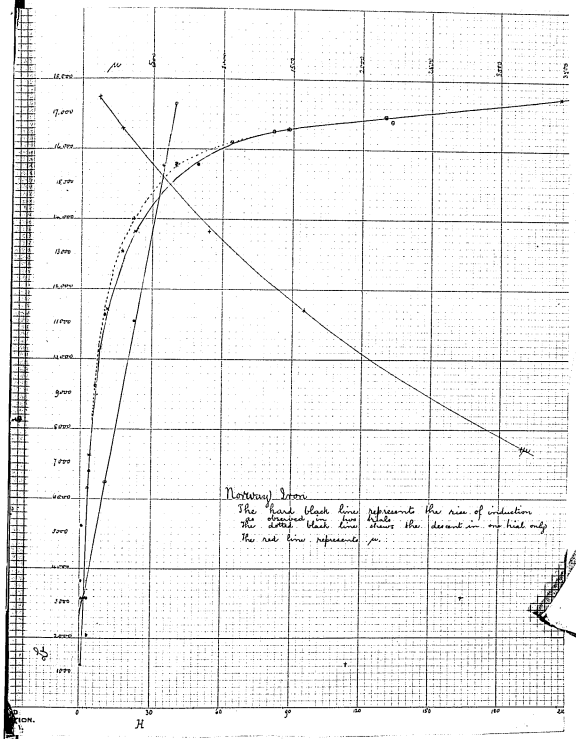
$$\therefore \quad \varphi = \frac{3.03 \times 1.511}{3.09} \times 10^{5} = 1.482 \times 10^{4}$$

$$\frac{4\pi nc}{\frac{C}{a\mu}} = \mathcal{E} \qquad \therefore \quad \frac{1}{\mu} = \frac{4\pi nca}{C\mathcal{E}}$$

$$\rho = \frac{1}{\mu} = \frac{1.257 \times 6.442 \times 6.02 \times \text{amperes}}{56.36\ \varphi}$$

$$= \frac{86.2\ a}{\varphi}$$

$$\mu = \frac{1.16\ \varphi}{100\ a} = \frac{1.927\ \varphi}{10\ a}$$



Determination of Galvanometer Constants.
by Silver Electrolysis

October 16th. The fine wire coil of the Obach Galvr, the fine wire coil of the Dumoncel Galvr + the fine wire coil of the Gaugain galvr were connected in series with a battery and a silver voltameter.

The weights of the plates were (1) 16.2650 (2) 17.5390

+ after heat (1) 16.5255 (2) 17.2760

+0.2605 −0.2630

0.2618

The current was flowing during 136 g mins (821140 seconds)

The deposit per second would be 0.000003187 g. = 0.000285 amp

The mean Obach deflection was 1.21 ± = = 0.42405

" " Dumoncel " " 52.' ± = tan⁻¹ 1.27994 = 0.44490

" " Gaugain " " 15°15' ± = tan⁻¹ 0.27263 = 0.09562

Previous determinations Sept. 12th 1888 made these constants 0.398 0.46874 and 0.0951 respectively, discrepancies −6.5 · +4 and 0.7% respectively.

A comparison between the Einheit + the Obach gave 3.2 divs. equivalent to 1.215 on Obach scale = 2.863 so that the reduction factor for the Einheit is thus 0.89446 or it overestimates 11.8%

On the 13th Sept. 1888 the Obach fine wire constant gave = 0.40445

" " Dumoncel " " " = 0.42286

in ratio to those of 0.9528 and 0.9546 respectively.

Permeability Measurements continued.

October 17th. Second series after remagnetising ballistic needle.

No. of Obs.	Mean ext. Galvr. Defl.	Amperes	Mean Ballistic throw	q $\times 10^{-5}$	$2q$	2π	Flux total in Ballistic est.	H	μ	ρ	Flux of outer tube	Capacity for Inductn	Induction Kilomaxwells
1	0 Einheit	0	0								13.47	3.0	40.41
2	0.050	0.045	111	1.511	1.4824	2460	39,300	0.967	1919		13.47	2.70	36.34
3	0.093	0.083	291.5	4.004	3.926	6520	"	1.783	2740		13.48	2.90	39.08
4	0.179	0.160	1355	4.876	8.727	14,500	58,300	3.437	3160		13.48	2.80	37.75
	Obach		186	2.555	9.708	16,470	205,200						
5	0.100	0.506	294	4.038	13.76	22,860	"	10.87	1580		13.48	2.40	32.35
6	0.208	1.052	180	2.472	16.43	27,290	205,300	22.60	906		13.48	1.95	26.29
7	0.370	1.976	205	2.816	18.71	31,080	"	40.30	578		13.50	1.58	21.30
8	0.811	4.102	219	3.008	19.98	33,180	"	88.14	283		13.50	1.30	17.55
9	1.940	9.608	231.5	3.180	21.13	35,100	"	206.4	129		13.83	1.04	14.39

I Clark cell both before and after series gave throw of 104 divs ± thus it @ 23.5°C. = 1.4285 microvolts. = 72.9 divs per microvolt

The values of μ here obtained compare with Hopkinson's as follows

h	Ours	Hopkinson	h	Ours	Hopkinson	h	Ours	Hopkinson
8000	2900	2520	13000	1110	1100	17000	205	190
9000	2470	2270	14000	850	820			
10000	2050	2000	15000	620	570			
11000	1710	1700	16000	400	310			
12000	1400	1410						

Measurement of the Galvanometer Constants by Electrolysis

October 19th 1889

Arthur Lehmann.

Ohach fine wire coil in circuit with the Bunsen.
Same silver plates + 25% solution

Weight before test	#1	16.4090	
	#2		17.2602
Test lasted 23 hrs = 82800 sec			
After	#1	16.6698	
	#2		16.9962
		0.2608	0.2640

Mean Ohach deflection 1.2076
Bunsen 3.089 milliamperes.

$0.26210 / 82800 = 2.624 \times 10^{-7} / 0.828 \times 10^{5} = 3.17 \times 10^{-6}$ $\quad 0.26210$

$3.17 \times 10^{-6} \div 1.11815 \times 10^{-3} = 0.002834$ amperes.

Ohach constant $1.2076 / 2.8334 = 0.4261$ per milliampere. (factor 2.347)
Bunsen $3.089 / 2.8334 = 1.090$ " " (" 0.9174)

On the roughly estimated cost of transmitting power from Niagara to a factory 3 miles distant! (say 16000 ft)

By formula on page 72

$l = 32000$

$E = 15{,}000$ (20,000 #)

$d = 20$

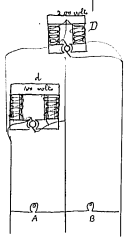
$v = 800$

$$\# W = \frac{1.346 \times 1.5 \times 10.24 \times 10^{11}}{6.4 \times 10^{5} \times 1.6 \times 10^{3}} = \frac{2.019 \times 1.024 \times 10^{11}}{10.24 \times 10^{8}} = 2019 \text{ tons}$$

= @ \$ 450 per ton \$900,000 dollars roughly.

Dynamo test for a new form of 3 wire System 19th October 89.

Trial the following arrangement



D is a 200 volt dynamo
d " 100 " "

The field magnets of D are so connected with the feeders that a short circuit on A takes the current off one limb and a short circuit on B takes the current off the other limb, thus keeping the pressure down to 100 volts.

A short circuit at B had the desired effect the lamp A flickered brightly and then resumed normal illumination.

A short circuit at A did not succeed in lowering the P.D. on B more than 20 volts leaving 180 there. This was due to the fact that the fields were not nearly saturated and 200 volts on the ~~left~~ right hand limb nearly had the same effect as 200 volts on both limbs.

Resistance was thrown into the right hand limb circuit till the machine would just excite but the reduction expected did not take place 160 volts being still left on B, but there is little doubt that if the magnets had been nearer saturation the plan would have succeeded.

Test of Car Brake Motor.

This motor has its armature shaft on centres and fitted with a worm of pitch. This worm engages in a toothed wheel on a vertical axis. Above this toothed wheel of radius " fits a friction cast iron disk whose rim has a radius of 4.8". This disk also has spurs and a chain at a radius of 6.0" running about 30" to a smaller sprocket on the ordinary brake shaft. The small spur wheel has a radius of 1.94" so that the power is multiplied 3.1 times. A drum was fitted to the vertical shaft had a rope attached to it at one or two different radii and the rope ran over a pulley down to a box of weight. By observing the current and p.d. on the motor and also the weight lifted and leverage a rough test of the efficiency was obtained. Thus calling the weight p the effective lever radius l" the spur ratio 3.1 and the observed angular velocity of the spur disk ω, the power delivered by the machine in addition to its own friction and the friction at pulley + shaft bearing $= \frac{3.1 p l \omega}{8660}$ watts $= 3.58\, p l \omega \times 10^{-4}$

1st trial p 32 lbs
l 27"
ω 0.405
$p + 32$ lbs $= 64$ lbs; $w = 125$; 0.165 HP
43 volts + 11.5 amperes = 495 Watts
Nett efficiency 25 % 0.25

2nd trial p 52
l 28.3
ω 0.340
$p + 32$ lbs $= 84$ lbs; $w = 171$; 0.239 HP
42 volts + 12 amperes = 504 Watts
Nett efficiency 34 % 0.34

3rd trial p 25.8
l 21.5
ω 0.385
$w = 76.5$; 0.10 HP
46 volts + 10.5 amperes = 483 watts
Nett efficiency 15.9% 0.16

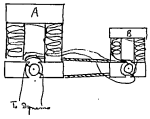
4th trial p 35.8
l 26.5
ω 0.425
$w = 144$; 0.19 HP
46 volts + 11 amperes = 506 Watts
Nett efficiency 28 % 0.28.

5th trial running light $\omega = 0.523$ .52 volts + 8 amperes = 416 Watts.

Description of an Experiment

Made on the 29th October of the starting power of motors when their field magnets are not supplied.

The 200 volt dynamo (#2 sig. wound for 200 volts) was connected up through adjustable resistance, and by means of its pulley a small 750 Watt machine was driven in such a manner as to react and supply its field magnets. It was found that about 80 amperes were necessary to start the 200 volt machine under these conditions. It then rapidly acquired speed and in ten seconds from the time of making contact had raised the e.m.f. of the small dynamo up to and even beyond the normal.



A 200 volt dynamo armature supplied by 90 amperes running as motor driving B an dynamo which in turn excites both fields.

When the belt was removed about 75 amperes was required.

With the Municipal 16 amp. machine under similar circumstances about 25 amperes was sufficient for the first 2 trials to start it. After that 40 amperes were failed

On the cost of copper required to transmit 20 000 HP from Niagara to Buffalo.

The distance is taken at 17 miles direct or 20 miles including the returns to grounds. The P.D. at dynamo terminals to be 6000 volts. The price of copper to be 19 cents per lb. or $4.25.50 per ton in wire. No leakage assumed.

The formula by page 72 is $W = 0.1346\, E^2 / v^2 d\,(100-d)$

Here $l = 1.056 \times 10^5$ $\quad l^2 = 1.115 \times 10^{10}$

$E = 1.5 \times 10^4$

$v = 6.0 \times 10^3$ $\quad v^2 = 3.6 \times 10^7$

$$\left.\right\} W = \frac{6.25 \times 10^5}{d\,(100-d)} \text{ lbs.}$$

% drop	HP generated	Tons of copper	Investment in copper	% drop	HP generated	Tons of copper	Investment in copper	% drop	HP generated	Tons of copper	Investment in copper
5	21,050	1320	562,000	18	24390	424	181,000	31	28960	292	124,000
6	21,180	1110	472,000	19	24690	407	173,000	32	29410	287	122,000
7	21,500	962	409,000	20	25000	391	166,000	33	29850	282	120,000
8	21740	847	360,000	21	25320	377	160,000	34	30300	279	119,000
9	22,000	764	325,000	22	25640	364	155,000	35	30770	275	117,000
10	22,200	694	295,000	23	26000	353	150,000	36	31250	271	115,000
11	22,470	640	272,000	24	26320	342	146,000	37	31750	268	114,000
12	22,730	592	252,000	25	26670	333	142,000	38	32260	265	113,000
13	22,990	552	235,000	26	27030	325	138,000	39	32790	263	112,000
14	23250	518	221,000	27	27400.	317	135,000	40	33330	260	111,000
15	23520	490	209,000	28	27770	310	132,000				
16	23810	465	198,000	29	28170	304	129,000				
17	24100	442	188,100	30	28570	298	127,000				

Taking the investment per HP at $28 we have.

% drop	HP gen.	Copper invested	Total investment	%	HP gen.	Copper invested	Total Investment	%	HP generated	Copper invested	Total investment
10	621,600	295,000	916600	15	658,840	209,000	867,840	20	700,000	166,000	866,000
11	629,160	272,000	901,160	16	666,680	198,000	864,680	21	708,900	160,000	868,000
12	637,440	252,000	899,440	17	674,800	188,000	862,800	22	718,000	155,000	873,000
13	643,720	235,000	878,720	18	682,920	180,000	863,920	23	728,100	150,000	878,000
14	651,000	221,000	872,000	19	691,200	173,000	864,200	24	737,000	146,000	883,000

So that for 6000 volts at machine terminals, 20 miles of line copper at 19 cts per lb. and the cost of installing 1 HP at Niagara $28 in dynamos + turbines, the maximum economy is reached at 17% drop delivering 3000 amperes at 4980 volts at motor terminal in Buffalo.

On the Niagara Estimates contd :-

Required to deliver 20,000 HP nett in Buffalo, on the premises of the consumer, the efficiency of the motors being 85%, the drop in the motor mains 5%, the efficiency of the double conversion in Buffalo central station 85.5%, the drop in the main line 15%, and the efficiency of the generating dynamo 93%. Also as regards light the drop in the feeders mains to be 12%, (8% in feeders 4% in mains).

Nett efficiency $0.93 \times 0.85 \times 0.855 \times 0.95 \times 0.85 = \cancel{0.482}\ 0.546$ say 0.55

so that for 20,000 HP delivered at the motor belt 18200 must be generated and the Nett efficiency for the lamps $0.93 \times 0.85 \times 0.855 \times 0.88 = 0.595$ say 0.6

so that for 10,000 HP delivered as light 16700 must be generated.

Total 35,000 generated HP at the dynamo shafts in Niagara.

or 32,500 HP (24,200 kwts) at machine terminals. =

(20,650 -)	. High Motor	-	Buffalo	
(17,650 -)	. Dynamo	-		(motor 9,290, lamp 5360)
(8,860 -)	. Motor Consumer	-	-	
10,620 HP (7,500 -)	. - belts	-	-	7400
10,000 HP (7,400 -)	. Lamps	-	-	

To deliver 20,650 kwts at Buffalo at 20 miles distance including ground returns and at 6000 volts generating pressure at M.T.

The c.millage is $\dfrac{20.650 \times 1.056 \times 10^{13}}{36 \times 10^{6} \times 15 \times 85} = \dfrac{2.065 \times 1.056 \times 10^{17}}{3.6 \times 1.5 \times 0.85 \times 10^{10}} = \dfrac{2.181}{4.59}$

$= 4.75$ million cmils

$= 4.75 \times 10^{6} \times 1.056 \times 10^{5} \times 3.015 \times 10^{-4} \times 2.24 \times 10^{3} \times 6.346 \times 10^{-3}$

$= 675$ tons @ 19 cent per lb ($425.00 per ton) = $287,400 copper.

this is if overhead wire used.

If cables be employed, the distance will be increased to 22 miles by the canal or river route via Tonawanda, and this will bring the Cmillage up to

$\dfrac{2.065 \times 10^{17} \times 1.162 \times 10^{5} \times 10^{7}}{36 \times 1.5 \times 0.85 \times 10^{10}} = \dfrac{2.40}{4.59} = 5.23$ million $= (5.5$ stranded$)$

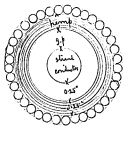
Each cable would have a strand 0.5" diam = 250,000 cmils so that there would be 22 cables in all, and there would be 14 spare cables so that in all there would be 6.5 million cmils $= 6.5 \times 10^{6} \times 1.162 \times 10^{5} \times 1.346 \times 10^{-3} = 1020$ tons $= \$432,700$ in copper. There would be 3/8" thickness of g.p. on each cable = diameter of core 1.25" + the area of g.p. $= \pi\{(0.625)^2 - (0.25)^2\}$

$\pi(0.391 - 0.063) = \pi(0.328) = 1.03$ sq. in. say 1 sq. in.

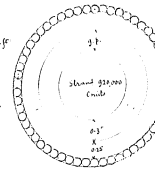
1346 feet would weigh 61 lbs or 0.045 lbs. per foot and there would be $1.162 \times 22 \times 10^{6}$ feet $= 109 \times 10^{6}$ lbs $= 109.00 \times 10^{3} = 48.7$ say 500 tons g.p.

This makes rather too thick a coating. If ½" covering be adopted as shown in the figure, then the g.p. would be in area $\pi(0.187) = 0.586$ sq. in say 0.6 sq. in. and the total weight would be 300 tons. The hemp would be ½" thick and there would be 37 # 11 B&S wires weighing each, weighing 210 lbs per mile = 225 lbs per knot mile = 49.50 lbs per cable = 108,900 lbs in all = 48.6 say 50 tons iron wire

$\pi(0.75^2 - 0.5^2) = \pi(0.563 - 0.25) = \pi(0.313) = 0.98$ sq. in. = 1146 feet per cubic foot of 40 lbs = 0.278 lbs. per foot $= 7.1 \times 10^{6}$ lbs = 3200 tons hemp

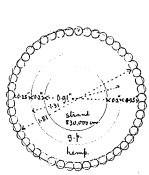


	cmils	lbs per ft	Total wt tons	cost per ton	Total cost
copper	920,000	2.5	1150	@ $425.50	$490,000
g.p.	1,500,000	0.71	300	$4480	1,344,000
hemp	1,850,000	0.64	166	$560	93,000
iron	800,000	2.4	1000	$112	112,000
					2,039,000



8500 volts P.D. at Niagara M.T. { 60,000 ℔ at motor bills Buffalo
10,000 ℔ in lamp at

	cmils	lbs. per ft	Tied to off.	Total lbs	per ton	Cost Total
copper	830,000	2.50	420,000	470	$425.50	200,000
g.p.	890,000	6.36	"	60	$4500	270,000
hemp	1,560,000	0.334	"	64	$560	36,000
iron	720,000	2.9	"	375	$112	42,000
						$548,000



With the formula $C = \sqrt{\dfrac{\pi^2 K d^3}{0.48 R \log_e \frac{D}{d}}}$

$d = 2.31$ $\quad \log_e \frac{D}{d} = 0.365$
$D = 3.33$
$R = 1.7 \times 10^{-6}$
$K = 4.9 \times 10^{-3}$

$$\sqrt{\frac{10 \times 4.9 \times 10^{-3} \times 2.31 \times 2.31}{4.8 \times 10^{-11} \times 1.7 \times 10^{-6} \times 0.365}} = \sqrt{\frac{2.56 \times 10^{7}}{2.98 \times 10^{1}}} = 10^{3}\sqrt{0.859} = 930 \text{ amperes.}$$

0.91" diam. = 0.650 sq. in.
0.650 × 6.625 = 4.20 sq. millimetre.
0.2" = 5.08 mm.

If on the other hand the cables could be stranded up to a million cmil say) 920,000 each then six cables would serve and eight might be laid making a total of 7.36 million cmil 0.3" g.p. 0.25" hemp + 56 # 11 B.W.G wires outside 0.12" diam.

The area of g.p would be approximately π ~~(0.3² − 0.5²) = π × 0.34 sq. in.~~ $\pi(0.8^2 - 0.5^2) = \pi(0.64 - 0.25) = \pi(0.39) = 1.195$ sq. in.: say 1.2 making 0.71 lbs per foot and there are $8.0 \times 1.162 \times 10^5 = 9.3 \times 10^5$ feet $= 6.6 \times 10^5$ lbs $= 6600 \times 10^2$ lbs. = 295 say 300 tons g.p. for there are $1.5 \times 8 = 12$ million cmil of g.p. in all paths per foot = 2 million of copper in weight or 5 times the weight of copper.

The hemp would be in area $\pi(1.05^2 - 0.8^2) = \pi(1.103 - 0.64)$ $= 0.463\pi = 1.455$ sq. in. $= 1{,}853{,}000$ cir. mils. or in all 14.82 million cmil $= 1.05$ mm cmils. of copper roughly) $= \frac{1}{5}$th weight of copper = 200 tons.

or more accurately) 17.46 cubic in. per foot = 0.64 lbs. $= 37.2 \times 10^{4}$ lbs = 166 tons

There are 56 # 11 wire each weighing 225 lbs per mile $= 2.39$ lbs per foot $= 2.39 \times 9.3 \times 10^5 = 22.2 \times 10^5 = 2220{,}000$ lbs = 1000 tons

+ the copper $7.36 \times 3.015 \times 1.162 \times 10^5 \div 2240 \times 425.50$ =

If the e.m.f at the Niagara generating terminals be 8500 volts then the circular mileage at 20 miles distance all included

$$= \frac{10^{9} \times 20650 \times 1.056 \times 10^{5}}{8.5^{2} \times 10^{6} \times 15 \times 85} = \frac{2.065 \times 1.056 \times 10^{17}}{7.225 \times 1.5 \times 0.85 \times 10^{6}} = \frac{2.18 \times 10^{17}}{0.921 \times 10^{6}}$$

$= 2.37$ million cir. mile $= 320$ tons. and allowing 33⅓% for spiral cable + 1.56 tons + 5% for stranding = 4.50 tons = 4 cables of 0.79 + 0.4 = 830,000 c.mils strand = 0.91" diam. The e.m.f at the high motor terminal will be $0.85 \times 8500 = 7230$ and the current will be 2856 amperes in all divided among 3 cables will be 952 amperes each.

The g.p will be in area $\frac{\pi}{4}(1.31^2 - 0.91^2) = 0.7854(1.716 - 0.828)$ $= 0.7854(0.888) = 0.698$ sq. in. per foot 8.34 cubic in. + 1 c.i. weight $\frac{64}{172.8} = 0.0369$ lbs. ∴ wt. per foot = 0.297 lbs. and the total weight $= 4.224 \times 10^5 \times 0.3 = 12672 \times 10^5 = 12672$ lbs = 56.6 tons say 60

The hemp will be approximately $\frac{\pi}{4}(1.91^2 - 1.31^2) = 0.785(3.276 - 1.716)$ $= 0.785(1.56) = 1.225$ sq. in and 1 foot = 14.7 cubic in. and each c.in weighs $\frac{20}{172.8} = 0.0232$ lbs. so that 1 foot weighs 0.34 lbs or in all 143800 lbs = 64 tons.

There will be ~~56~~ 56 # 11 B.W.G wires each 14,400 cmil = 722,000 1 cubic in. of iron weighs $\frac{480}{172.8} = 0.2778$ lbs. per linear foot = 3,336 = 2.62 lbs per foot million cmil

---

The temperature of the canal water must be in summer no higher than 70°F = 21°C. and the temperature of the g.p. in the interior must never rise above 90°F = 32°C. so that 10°C will be the max. temp elevation permissible

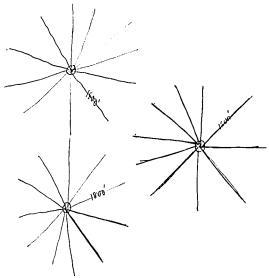
$$C = \sqrt{\left\{\frac{\pi^2 K d^3}{0.48 R} t \times \frac{D}{10 + 3D \log_e \frac{D}{d}}\right\}}$$

$K = 4.8 \times 10^{-3}$
$d = 0.91" = 2.31$ $\quad \frac{D}{d} = 1.4441$ $\quad \log_e \frac{D}{d} = 0.365$
$D = 1.31" = 3.33$
$R = 1.7 \times 10^{-6}$

$$\sqrt{\frac{10 \times 4.8 \times 10^{-3} \times 2.31 \times 2.31 \times 10 \times 3 \times 3.33}{0.48 \times 1.7 \times 10^{-6} \times (10 + 3 \cdot 1.05)}} = \sqrt{\frac{2.56 \times 10^{6}}{1.1114}} = 10^{3}\sqrt{\frac{25.6}{1.1114}} = 10^{3}\sqrt{23.0}$$

$= 480$ amperes

Feeder system.



On the amount of money necessary to invest in copper for 150,000 lamps in Buffalo at a mean distance of 1800 feet from the generating stations. Each lamp to absorb 50 Watts 8% drop in feeders 4% in mains + the neutral to be as large as the outside. No account taken of all the lie mains. The calculation deals practically with feeders 1800 feet long.

The total energy to be delivered is 7500 kilowatts at 8% drop ∴ circular millage

$$= \frac{7.5 \times 10^3 \times 3.6 \times 10^3 \times 10^3}{2.40 \times 2.40 \times 10^6 \times 8 \times 92}$$

$$= \frac{27 \times 10^{18}}{4.24 \times 10^7} = 63.7 \text{ million.}$$

Wt $= 63.7 \times 3600 \times 0.1346 = 309.0$ tons

+20% for neutral $= 370.0$ tons.

$$= \frac{1.346 \times 7.5 \times 10^3 \times 3.6 \times 10^3 \times 3.6 \times 10^3}{2.40 \times 10^2 \times 2.40 \times 10^6 \times 0.8 \times 10^1 \times 0.92 \times 10^2} = \frac{131 \times 10^9}{4.24 \times 10^7}$$

$= 309$ tons $\quad$ 370 tons

@ \$425.50 = \$157,500

On the amount of money necessary to invest in copper for 3330 HP (2500 kwt) at a distance of 4300 feet. (8600 h.p.) at 4% drop and 800 volts M.T. to be distributed at this mean distance in Buffalo

The circular millage

$$= \frac{2.5 \times 10^3 \times 8.6 \times 10^3 \times 10^3}{8.0 \times 8.0 \times 10^6 \times 4 \times 96}$$

$$= \frac{21.5 \times 10^{18}}{2.46 \times 10^6} = \frac{21.5 \times 10^{12}}{2.46 \times 10^4} = 8.74 \text{ millions}$$

The weight is $= 8.74 \times 3.015 \times 8600/2240$

$$= \frac{226700}{2240} = 101 \text{ tons @ } 425.50$$

\$43,000

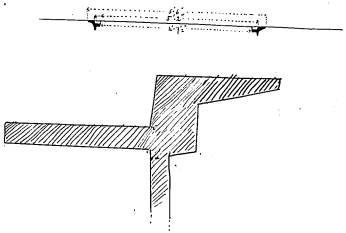
$$= \frac{1.346 \times 2.5 \times 10^3 \times 8.6 \times 8.6 \times 10^3}{8.0 \times 8.0 \times 10^6 \times 4 \times 96} = \frac{249 \times 10^9}{2.46 \times 10^4}$$

$$= \frac{2.49 \times 10^{18}}{2.46 \times 10^4} = 101 \text{ tons} = \$43,000$$

Cablegram sent 1 XI. 19 To Siemens Bros London from Robson N.Y.
"Probable approximate price of one hundred knots lightly armoured cables with stranded core four hundred and twenty square millimeter and gutta-percha five millimetre thick in several layers with intermediate compound."
Reply received 5 XI 19 To Robson Orange from Siemens
£ 1750 per knot exclusive packing delivered works Woolwich.

The water distance to City Hall is 22 statute miles
4 cable are 88 " $\times 0.876 = 77.1$ knot
£1750 @ 4.90 = \$8576 $= \$661,000$. for \$22,000

Cross section of track



Full sized rough cross section of rail on Orange road, upper part only. Each rail 30 feet in length.

Characteristic Curve of 200 volt Dynamo Machine.

27th October 1889.

Ran the 200 volt machine light without load & measured the voltage at its terminals by potentiometer while observed current strengths passed through the fields.

No. of Obs.	Speed of armature per min.	Observed reading of Jaeger ammeter in cross shunt	Corresponding current in amperes	Res. on Galv. ch.	Total res. between terminal	Ratio	Voltages
1	1495	0·145	0·113	345	9850	28·56	40·87
2		1·00	0·202	200	9730	48·75	69·8
3		1·45	0·270	172	9975	58·01	83·0
4		1·35	0·254	170	9873	58·10	83·2
5		1·90	0·288	142	9943	70·04	100·2
6		2·45	0·320	127	9930	78·18	111·8
7		3·02	0·370	112	9913	88·52	126·7
8		3·45	0·394	103	9913	96·26	137·7
9		3·85	0·445	97	9997	103·0	147·4
10		4·35	0·475	90	9991	111·0	158·9
11		4·68	0·496	87	9987	114·8	164·3
12		4·52	0·480	89	9990	112·2	160·5
13		4·95	0·525	82	9983	121·8	174·3
14		5·48	0·556	78	9979	128·0	183·2
15		6·08	0·622	74	9975	134·8	192·9
16		6·51	0·667	70	9970	142·4	203·8
17		7·12	0·718	66	9966	151·0	216·1
18		7·60	0·814	63	9963	158·1	226·3
19		7·98	0·885	61	9971	163·5	234·0
20	1500	8·30	0·950	59	9959	168·8	241·6

Measurements of resistance on Orange Track. of the Cross Town Rail Road

A 0 1 2 3 4 5 6 7

B

Line A	from	0 to 1	on the same metal		0·01 ω	Hyppion Distance	15 feet
B					0·01 ω		
A		0 - 2	across 3 junction		0·44 ω	roughly	60
B					0·84 ω		
A		0 - 3		5	0·84 ω		108
B					1·24 ω		
A		0 - 4		7	0·94		192
B					0·24		
A		0 - 5		9	1·09		261
B					1·34		
A		0 - 6		11	1·14		318
B		6			1·14		
A		0 - 7		15	1·34		411
B					1·44		

Average resistance of each junction about 0·1 ω and variable.
Res. at 0 from Track to Rail 19 ω roughly and with a car on the same pair of metals 14 ω

Design for a four pole continuous current transformer

The bar motor is intended to deliver 10 HP. to its axle, if the efficiency of the motor be 85% then the HP. delivered to the motor will be 11.75. also if the drop in the line be 15% then the HP. at machine terminals will be 13.8: and if the drop in the armature be 5% the HP. absorbed by the machine secondary will be 14.6. If 2.5 HP. be consumed in keeping the machine up to speed in foucault currents, friction, and magnetism, then the power delivered to the transformer will be 17.1 HP in the primary ct. with 18 HP. at m.t. in the engine room 10 HP shall be realized at the car axle.

The transformer will receive its pressure at m.t. and will deliver it pressure at m.t. 20 volts.

13.8 HP = 10,300 Watts so that the current will be 515 amperes. The diameter of the armature ring to be 24" externally and 7" broad. The peripheral speed to be 5000 feet per min. The res: of the machine to allow 1 volt drop at full load = 0.00195 ω and the resistance of each quadrant must not exceed 0.000488 ω. Allowing an average field of 8 gauss the peripheral velocity 2500 cms per sec: the effective length of each turn 2.3 cms, then if x be the no: of turns in the quadrant

$$x = \frac{21 \times 10^8}{8.0 \times 10^4 \times 2.3 \times 10^1 \times 2.5 \times 10^3} = \frac{21 \times 10^8}{4.6 \times 10^7} = 45.7$$

keeping 45 turns per quadrant or 180 turns for the whole ring the res: per turn of the coarse wire ct: is to be 0.000001 or 10 microhms. If the length be 25 cms then the res: per cm must be 0.4 microhm and copper @ 55° has a resistivity of 2 microhms so that there must be 5 sq: cms: of cross section. Allowing 10% for insulating space 5.5 sq: cms. The diameter of the exterior section center being 24.5" = 62.2 cms = 195.5 cms. periphery = 1.09 cms per turn so that the winding would have to be 5 cms. deep. to obtain the required result.

Keeping 20 bars in the commutator, the only reduction possible from 180 turns in the circumference is to 20 turns in the circumference = 22.5 per quadrant. The field necessary for this must average

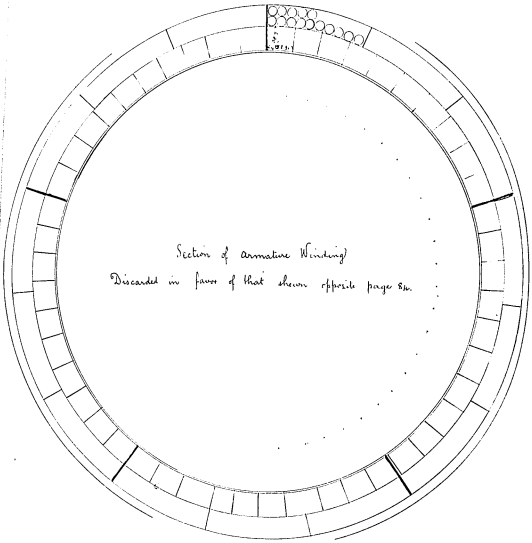
$$\frac{21 \times 10^8}{2.25 \times 10^1 \times 3.0 \times 10^1 \times 2.5 \times 10^3} = \frac{21 \times 10^8}{16.88 \times 10^5} = 1244$$

which must therefore be provided for.

This being allowed the res: of the single turn reduces to 20 microhms and the res: per cm: $\frac{20}{30}$ = 0.67 microhm the cross section to 3 sq: cms: with 10% allowance 3.3 and the linear space on the periphery being 2.18 allows 1.38 cms thickness of bar. But sufficiently increasing the cross section within the armature the thickness on the outside can probably be proportionately diminished to the proper amount.

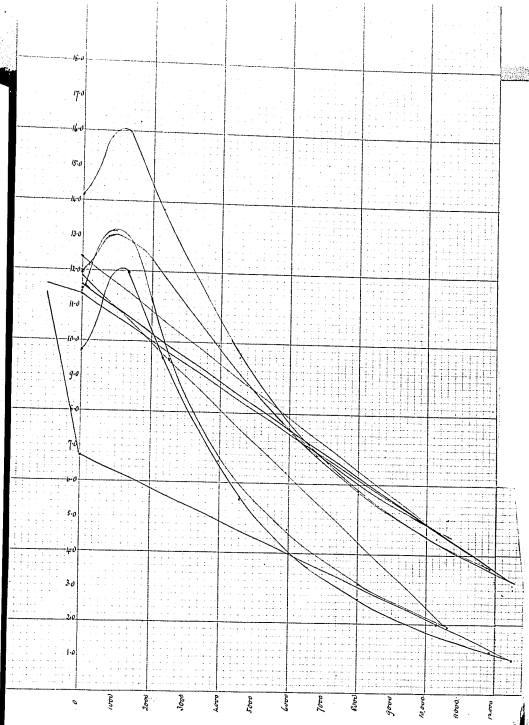
The field wire ct: must generate 1050 volt, it will therefore have 50 turns as many turns as the coarse wire ct: there will thus be ~~150~~ 90 × 50 = 4500 turns in all or 1125 turns per quadrant. or 25 turns per commutator bar (of 180 in the circle). 17.1 HP = 12,760 Watts at 1050 volt = 12.15 amperes in primary ct: at full load. That will be 3.04 amperes in each quadrant and allowing 400 c.m. per ampere = 12.16 c.mm = #20 B&S. 0.035" bare or 0.040" covered. Allowing 18" (1.5 ft) per turn the length of wire on each quadrant will be 1690 = 141.25 ω and the res: of the whole machine 3.58 ω say 4.0 ω hot.

The diameter of the iron wire armature being 24" then covered with four thickness of oilpaper 24 × 0.0045 = 0.09 = 24.09" and the circumference 75.53". The internal diameter of the ring will be 20" and



Section of Armature Winding

Discarded in favor of that shown opposite page 8/m.



over the oil paper 19.95. circumference 62.68". this divided into 180 bars gives 0.3148" for commutator segment. Six turns will fit into this space and four deep will make a thickness of winding = 0.200". The diameter of the fine wire surface will thus be 24.44" and 19.55" respectively.

Calculations for a 2-pole transformer.

A #3 Edison machine has an output of 7.5 kilowatts
" #4 " " " " 10 " "
13.8 P = 10,280 Watts. By boring out the fields a little more and decreasing the speed and magnetism, the difference may be made up.

The diam. of the armature is 6.25" the length of 12" over the armature proper + 0.02" all over for 4 thicknesses of paper.

The fine wire commutator will be a regular M. vol. of 100 bars. The coarse wire commutator will be of regular No 20. of 50 bars. The E.M.F to be generated in the fine wire ct. = 1050 v.
" " " " " " coarse " " = 21 v.

A no 4 machine making 1600 revolutions per minute generates 125 volts. It has 1 no 9. B.W.G. wire twice around over 50 dis or 100 complete turns = 100 half turns on each side of the armature. Consequently the volts per wire are 1.25 at 1600 revs. if a trial speed of 2000 revs. be allowed, the volts per wire would be 1.563, and to generate 1050 volts 672 turns would be required or about 14 turns to each division if the magnetism were maintained.

The air space in a #4 is $\frac{7.25 - 6.25}{2}$ = 0.5" on a side. As a trial value the boring can be increased 0.25" in rad: giving 0.75" on a side. The c. millage of a #9 wire is 21,900 which for 80 ampere gives 275 X2 = 550 c. mil. per ampere. Allowing 450 c. mil for 12 ampere (full load) = 5400 c. mils for 2 wire = 2700 c. mils for one wire = 0.052". The nearest wire to this is #16 B.&S (0.0508" 2590 cmils = 430 cm per amp.) Allowing 0.016" for covering = 0.065". The magnetic field will be reduced for the same exciting power in the ratio of 3 to 2 or to 1.06 volts per turn at 2000 revolutions, but by adding 50% to the weight of copper (63 lb ratio) the original magnetic field where no iron is left in ct. may be expected in which case 15 wires per div = 750 turns round will be needed.

The clearance will be ⅛" all round = 0.125". The armature diameter is thus 7.5" over the wire. The armature body insulated is 6.3" in diam. leaving 0.6" for winding space. The total area of winding space is thus 0.785 (7.5² − 6.3²) = 0.785 × 16.56 = 13.0 sq. in. There will be 50 divs each 0.050" thick and 0.6" long = 1.50 sq. in. There will also be 3 thicknesses of paper in the coil = 0.015" and 22" around = 0.33 sq. in. ∴ 13.0 − 1.83 leaves 11.17 sq. in. of useful winding area. This halved leaves 5.58 sq. in. and 750 turns mean 1500 wire sections 0.0072 sq. in = 0.0108 less 0.015" = 0.0146"

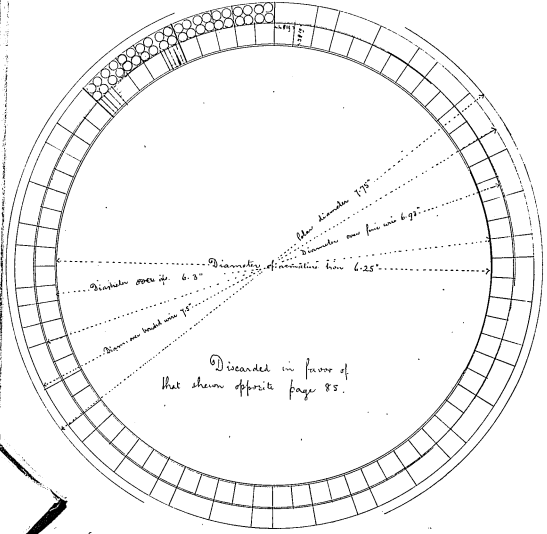
For the coarse wire ct. we have 5.58 sq. in: area and 30 conductor sections in this amount = 0.186" = (0.431)²

The circumference of the armature over the bare insulation 6.3π = 19.79" and 50 divs of fibre + paper 0.05 = 2.5" leaving 17.29" at base for winding #19 wire = 0.042 + 0.014 = 0.056" 309 turns round say 300 and 5 layers make up the 1500. There 5 layers = 0.28" + 7 thicknesses of paper 0.025 = 0.305" so that the diam over this wire = 6.93"

The circumference over the insulated fine wire = 6.93π = 21.77" allowing 5 divs each 0.05" = 0.25" leaves 21.52" bare circumference. The depth available being 0.285" = 2 wire 0.142" covered. 150 such wire = 21.3" so that each block is supplied by 20 wire #8 B&S (0.128") in 2 layers of 10 each or 150 turns round 300 half turns

Section of 10 kilowatt transformer armature.

#4 machine with poles bored out to 7.75" diam:
1050 volt fine wire c.m.f @ 2000 revs: or under
21 " coarse " " "
50 = conversion constant.
75 bars in fine wire commutator
15 " " coarse " "



(1) Discarded in favor of that shown opposite page 85.

Winding

Fine wire laged on first in 75 slots.
One #19 B.W.G 0.043" covers to 0.05". 10 turns round
Making in all 750 commutators in 5 layers 6 turns to the division
Coarser wire laged on outside in 15 slots.
Two #5 B+S wire 0.123" covers to 0.148" once round.
Making in all 150 commutators in 2 layers of ten per main slot.
About 4800 feet of #19 B.W.G wire weighing about 28 lbs. = 3530 c.m.s in all
" 500 " " #8 B+S " " 25 " = 329,000 " " "

The c.millage of #8 B+S is 16,380 and there are 10 wires in parallel = 163,800 and two such sets one on each side of the armature = 327,600 c.mils in all. Each such composite wire makes 75 turns round the drum, and each such turn is about 3·3 feet. so that the composite conductor is 24·75 feet in length. The res: of the armature is thus about $\frac{24.75 \times 11}{327,600} = \frac{292.25}{327,600} = 0.000892$ say 0·0009 ω and at 500 amperes the drop will be 0·45 volts. while the energy absorbed at full load will be $0.25 \times 10^4 \times 9 \times 10^{-4} = 2.25 \times 10^2 = 225$ Watts.

The c.millage of #19 B.W.G. wire is 1764 and the two sides of the armature give 3527 there will be 750 turns @ 3·2 feet = 2400 feet. the res: will thus be $\frac{2.400 \times 10^3 \times 11}{3.53 \times 10^3} = \frac{28.4}{3.53} = 8.05$ ω. hot, the drop at full load 98 volts and the energy absorbed 1200 Watts. (on the amp for the shunt)

This arrangement favors the coarse wire circuit at the expense of the fine.

Suppose 96 commutator bars in the fine wire commutator and 16 bars in that of the coarse wire.

The circumference over insulation wire = 19.79" and with one paper between each block and one fiber division at every third block = 96 × 0·0090" = 0·86" + 32 × 0·045" = 1.44 total 2·30" leaving 17·49" 17.49 ÷ 288 = 0·0607 − 0·014 = 0·0467 and #17 B+S = 0·0453 so that there will be this wire 3 times round per div: or 8640 turns in all the c. mils = 2050 or 2 in parallel 4100 ÷ 12 = 342 c.mils per amp. There will be 3 layers = 0·180" + 0·01 = 0·190 × 2 = 0·38 + 6·3 = 7·06" over insulated fine wire set. The circumference = 22·18". has 16 divisions of fiber @ 0·050 = 0·8" leave 21·38" ÷ 20·4 = 0·1048 − 0·014 = 0·091 and there will be two such layers = 0·182 × 2 = 0·364 = 7·42". Fourteen of these wire will be in parallel and each has 8230 c.mils or 115,200 c.mils in all + 2 such sets give 230,400 c.mils. 86 turns @ 3·3 feet per turn = 284 feet so that the res: of the coarse wire set hot will be $\frac{284 \times 11}{230,400} = \frac{286}{230,400} = 0.00124$ and

There will be 864 turns of 3·2 feet in the fine wire set = 2700 feet the c.mils 2050 of #17 B+S (0·0453") or 2 = 4100 so that the res: will be. $\frac{2700 \times 11}{4100}$, $\frac{297.00}{4100} = 7.24$ ω hot and the drop at full load c 87 volts while the drop in the coarse wire is 0.62 volts. = 3%
" " " fine wire is ·87 " = 7·6%
Total efficiency taking out magnet friction 89·3%

---

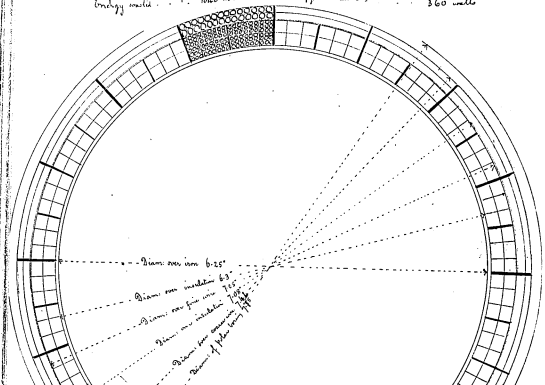
1 sq. cm of iron has a res: of 9.6 microhms @ 0°C and at 20°C 10.6 microhms 1 sq. in = 6.45 sq. cms. = $\frac{10.6}{6.45}$ = 1.64 microhms and 1 foot = 50·1 microhms so that 300 feet of distance = $\frac{600}{6.45}$ feet of rail = 30,000 microhms = 0·003 ω for one square inch of metal = 0·0015 ω for two inches = 0·001 ω for three

and with 500 amperes the drop would be 5 volts or if on full load at that distance the next transformer took half load then 250 amperes would give 2·5 volts drop = 19·8 − 2·8 = 17·3 volts at machine terminals.

The distance from the Engine Room to the Connecting point on the roads will be 2400 feet. The current supplied to one idle transformer will be 2·5 amperes, suppose and to 2 active ones 12 amperes each = 26·5 amperes. The p.d. at transformer terminals is to 1050 and at 50 volts drop = 1·89 ω 4800 feet = 0·000393 ω per ft. = #8 wire.

Cross Section of Continuous Current Transformer Armature (Full Size) for 10 Kwts.

Fine wire commutator 96 blocks about 20 volts per bar
Coarse - 16 . . 2.6 . . .
Speed reckoned at 1730 revs: per min.
Winding: Fine wire beneath 1 wire (#17 B.&S) = 0.0453" = 2050 c.mils (340 per amp/ft)
9 turns round = 864 turns in all.
Coarse wire above 14 wires (#11 B.&S) = 0.091" = 115,200 c.mils (1,160 per amp/ft)
over round = 16 turns round in all.
Coefficient of conversion 4.8.
Res: of primary 7.25 = Ret. Res: of secondary 0.0012 = Ret.
Drop in . @ f.l. 87 volts Drop in . @ f.l. 0.62 volts
Energy wasted . 1080 watts Energy wasted . . 360 watts



2700 feet of #17 B&S = @ 0.0062 lbs per ft. 16.2 lbs.
750 " #11 B&S = @ 0.024 - . 18 lbs
60 lbs on each limit of #11 B.W.G magnet wire = 120 lbs in all.

Leakage between Low Volt Mains

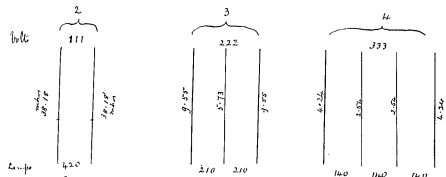
1st November. Two 24 foot iron rails (in ordinary) surface conditions were buried so as to be covered by about one inch of soil. They were placed in the courtyard, parallel to each other and 3 feet apart. They capers about.
The day preceding had been wet and the ground was damp but to make more certain of the thorough wetting, about 12 pails of water from the tap were thrown on the soil above and between them. By bridge w/ the minimum res: was about 100 - making the leakage 0.2 ampere. By upright ammetre, rather insensitive the leakage was 0.55 on m.m. scale = 0.13 ampere. By the Siemens small tangent galv: the deflection was 51° with each direction of current and tan 51° = 1.235 = 0.16 ampere. Taking the highest 0.2 ampere for 24 feet = 0.8 ampere per 100 feet = 8 amperes per 1000 feet and for 2750 = 22 ampere. By painting the rails with heavy coating of pitch, even this loss 22 × 20 = 440 Watts or 0.75 HP at station may be reduced indefinitely.

4th November. Magnetic Experiment for 3 wire system

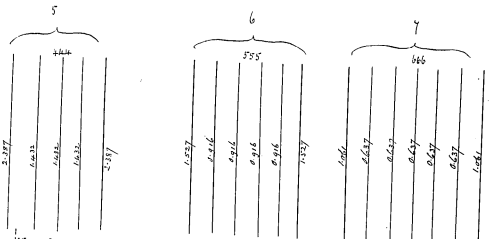
Tried the effect of short-circuiting one lamp out of the two represented in the diagram. The result was to bring 200 volts pressure on one limit and one lamp. This had resulted in every case in burning the lamp finally although the voltage would fall to 100 in about ten seconds.

The bore of the #10 fields has been increased from ~~7.25~~ 7.25" to 7.75" an increase of 0.25" radius. The entrefer previously was 0.5" and it is now 0.75". The reluctance of the air space has diminished the flux to 0.67 of its previous value and the leakage will bring it down to say 0.6. Consequently to restore the field its magnetic motive force should be increased 1.67 times. The reluctance of one limit of the magnet is 18.7 of #17 B.W.G. = 14340 feet and the diameter of the core is 7.4" so that the circum: = 1.94 feet = 2240 turns. or on both limits together 4480. The current at full load = $\frac{125}{56}$ = 2.23 so that the amptire turns are 9000 and 15,000 turns to be provided for.
The surface = 32 × 12 = 384 sq. in. = 2480 sq. cms = 100 Watts @ 25 sq. cms per Watt. = 200 Watts in all. @ 20 volts = 10 amperes = 1500 turns for 2 w. The length of each turn being 2 ft. length = 700 on each limit = 1500 feet per w = #11 wire diam: 0.120" = 0.120" end: the length begins 12" = 90 turns = 5 layers. = 1" dep. + the weight 121 lbs.
If #10 were used then would be 0.144" diam: covered .80 turns to the layers and 10 layers = 1 w on each + the total weight 189.

Neutrals 60% wt of outsides.



	2	3	4
Lamps	420	210 210	140 140 140
Amps	210	105	70
volts	100	200	300
Miles	76.46	24.83	13.56
ft	100	32.5	17.8
Saving		67.5	82.2
Saving on feeding		47.5	45.4
Distances attainable in terms of 2 wire		1.76	2.37
Area		3.09	5.62
Voltage of lamp which on 3 wire system would have equal economy		100	134.7



	5	6	7
Lamps	105 105 105 105	70 70 70 70 70	60 60 60 60 60
Amps	52.5	35.5	30
volts	200	500	600
Miles	9.07	6.78	5.07
ft of copper	11.0	8.8	6.14
Saving	88.1	91.2	93.86
Saving on feeding	33.1	26	21
ft . . . 2 com	82.1		
Dist. attainable on 3 wire	2.90		
. . . 3 .	1.44		
Area . . 2 .	8.4		
. . . 3 .	2.1		
Voltage of lamp — Economy	165		

Investigation of Copper Economy in 3 wire and multiple wire systems.

In the Brooklyn system of 3 wire mains and feeders, the lamps were 19,250 of 115 volts and 0·5 ampere, and with 10% drop in feeders and 17% in mains the feeders were 35,800 feet in total length embodied 15,250 million milfeet of copper and cost $69,000, while the mains were 60,800 feet embodied 8,040 million mil feet of copper and cost $56,400 each.

The cost of copper is related to the total cost of underground wiring in the following manner. (all material included) copper @ 19·2 per lb (mid-

Feeders

No.	Edison #	G.M.	G.M. Mult.	Weight copper per ft lbs	Manufacture cost of tubes per ft $	Relative cost of tube to that of conductor	No.	Edison #	G.M.	G.M. Mult.	Weight of copper per ft lbs	Manufacture cost of tubes per ft $	Relative cost of tube to copper
1	650	650,000	200,000	4·52	1·61	1·87	1	500	500,000	500,000	4·52	1·52	1·78
2	600	600,000	200,000	4·22	1·54	1·92	2	450	450,000	450,000	4·07	1·43	1·95
3	550	550,000	200,000	3·92	1·48	1·99	3	400	400,000	400,000	3·62	1·34	2·01
4	500	500,000	200,000	3·62	1·39	2·02	4	350	350,000	350,000	3·17	1·24	2·06
5	450	450,000	150,000	3·17	1·30	2·16	5	300	300,000	300,000	2·72	0·98	1·90
6	400	400,000	150,000	2·87	1·24	2·28	6	250	250,000	250,000	2·26	0·88	2·05
7	350	350,000	150,000	2·56	1·15	2·36	7	200	200,000	200,000	1·81	0·77	2·24
8	300	300,000	100,000	2·11	0·91	2·27	8	150	150,000	150,000	1·36	0·67	2·59
9	250	250,000	80,000	1·75	0·83	2·49	9	120	120,000	120,000	1·09	0·53	2·56
10							10	100	100,000	100,000	0·90	0·50	2·92
11							11	80	80,000	80,000	0·72	0·46	3·36

In the Brooklyn district the manufacturing cost of the tubes for feeders was $46,000 and the copper alone $20,300 roughly) or 2·27 to 1 and the mains $37,600 and copper alone $13,800, a ratio of 2·73 to 1. A reduction in the dimensions of copper in the feeder does not reduce the price of tube in same proportion.

Since in this district the ratio of the copper in mains to that in the feeders was about 2 to 3 and the neutral is 30% in the feeders of the outsides while equal to the outsides in the mains, it follows that setting all the lamps at the centre of distribution in each circuit, the neutral has 60% of the weight of an outside.

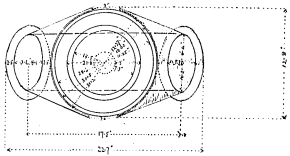
The general formula for the weight of copper in a n-wire system compared with that on the same system with 2 wire is

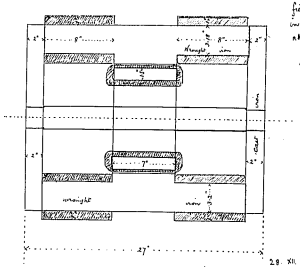
$$c = \frac{C}{(n-1)^2}(0.3n + 0.4)$$

where C is the 2 wire weight

The opposite page gives the conditions of various systems up to 7 wire for copper only. Thus the 3 wire system reaches 75% further than the 2 wire system and covers 3·1 times the area for the same weight of copper. The 5 wire system again will reach 2·9 times further than the 2 wire and 1·4 times further than the 3 wire, with areas 8·4 and 2·1 times respectively.

Car Motor 8





N.B. This elliptical field form was discarded in favor of circular sections as shown on page 60. Other particulars retained as here stated.

28. XII. 89.

Speed 1350 revs. per min
22.5 . . . .
= 1.45 m

Peripheral 4230 ft per min
2.250 cms . sec

Commutator Bars 60 =
Commutator 8 in dia

voltage Light 20
Loaded 15

amperes 75 amp + 20 in field Light
- 500 . + 15 . . loaded
Power absorbed 2 HP 1500 watts Light
" " 10 HP 7500 . loaded.

Winding Grammer ring
6 # 7 wire wire round to each division in
2 layers of 3 above and 3 of 2 below.
Res: of armature 0.0113 ω
" field coils 1ω each 2 series of 2
Arm 50 lbs # 7 B.W.G. s.c.
96 . # 13 . . . magnet.
Drop in armature full load = 0.6 volts.

On first trial with 20.5 volts on field in series and 1.1 ω on terminals Revolutions 85 per min with 3.1 . . . 288
which last fell to 220 on increasing field voltage to
This would promise 1350 rev. @ 14.5 volts terminal pd
The final history of this armature is recorded in Book III p. 137.

Alterations in the Car Motor Design.

The speed has been increased from 3000 to 4230 feet per minute or 1350 revolutions per min: The diameter on the iron being 11.25" or 11.30" over paper = 36.48" circum: $\frac{36.48}{60}$ = 0.608" width of one block. One third of this length = 0.203" or 0.188" allowing for insulation, and #7 = 0.180". Two such layers = 0.360" so that the diameter of the bore = 11.3 + 0.720 + 0.25 = 12.27" diam. The internal diam: of the ring = 8.47" and over paper 8.2" and at 0.5" inside = 7.4" . . 7.4 × 3.14 = 23.24" and this divided by 0.195 = 120 so that the winding will be 60 blocks each 6 wire in 2 layers of 3 broad above and 3 layers of 2 turns below.

The present cores are 4.5" in diam: so that their area = 6.36 sq. ins. for elliptical cores $\pi ab = \pi d^2$ and if $a = \frac{1}{2}$ then $b^2 = 2d^2$ or $b = d\sqrt{2} = 1.414 \times 4.5" = 6.36"$ and $a = 3.18"$
The length of the mean turn with 1" winding space will be

~~$\frac{\pi}{2}\left(\sqrt{3.5^2 + 6.5^2} + \sqrt{4.5^2 + 7.5^2}\right) = \pi\left(\sqrt{12.25} + \sqrt{20.25}\right) = \pi(3.5 + 4.5) = 25"$~~

$$\frac{\pi}{2}\left(\sqrt{\frac{3.2^2 + 6.4^2}{2}} + \sqrt{\frac{5.2^2 + 9.4^2}{2}}\right) = \frac{\pi}{2}\left(\sqrt{\frac{10.24 + 40.96}{2}} + \sqrt{\frac{27.04 + 70.56}{2}}\right)$$

$$= \frac{\pi}{2}\left(\sqrt{25.6} + \sqrt{48.8}\right) = \frac{\pi}{2}\left(5.05 + 6.98\right) = \frac{\pi}{2}\left(12.03\right) = 6.015\pi$$

$$= 18.9"$$

9.6 lbs of #13 B.W.G. wire 0.095" on all four cores = 24 lbs on each core @ 36.6 ft per lb : 8840 feet = 4 × 26352" ÷ 19 = 580 turns. 8 + 0.110 = 70 turns 9 layers. res: 1 ω per cut + all 4 in series = 4 ω . 18 ω give 4.5 amperes = 5040 ampere turns on each pair of limbs. = 6336 amp. Reluctance = 0.096 , flux = 1056,000

The ~~total flux~~ will be given by the ~~expression~~ equation

$$20 \times 10^8 = \phi \times 60 \times 22.5 \quad \therefore \phi = \frac{20 \times 10^8}{1.20 \times 2.25 \times 10^3} = 16 \times 10^6$$

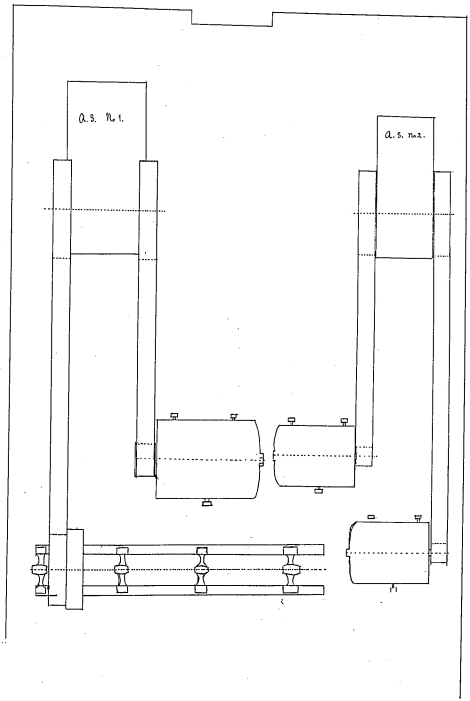
and allowing 30% for leakage gives 2,080,000 total lines.
The air spaces and winding spaces together (centres) constitute 2.5 cms and the area 750 sq. cms = $\frac{1}{300}$ = 0.0033 which with the armature rib proper may be taken as 0.006. The total number of ampere turns required is therefore $2.08 \times 10^6 \times 6 \times 10^{-3} / 1.257 = 9930 = 4965$ ampere turns on each limb. The surface of each limb is about 7" × 22" × 8" . 176 sq. ins = 1135 sq. cms. and allowing 10 watts per volt = 113.5 Watts per limb @ 7.5 volts = 15.2 amperes
13 wire 24 lbs on each limb and in two series will have 2 ω res: in each series = 15 – 20 amperes in the field altogether and 7.5 – 10 amperes in each limb = 10500 to 14,000 a.t. according to the voltage.

Res: of armature = 45 feet ÷ 12 = 3.75 feet of #7 wire = 0.0012 = length of wire = 500 feet of #7 = 50 lbs: in all.

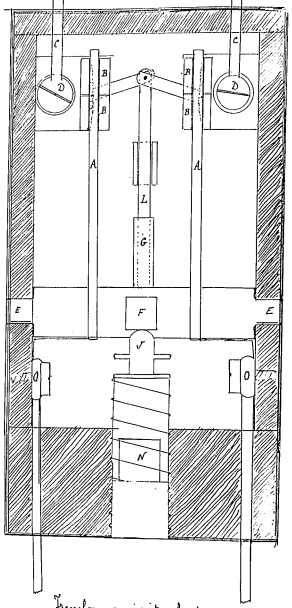
Ground Plan of Dynamo Room.

Scale $\frac{1}{40}$th actual size.

October 1889 before increasing capacity of dynamos.
No 1 engine driving the shafting + 1 #20 No 2 engine driving a pair of #10s.



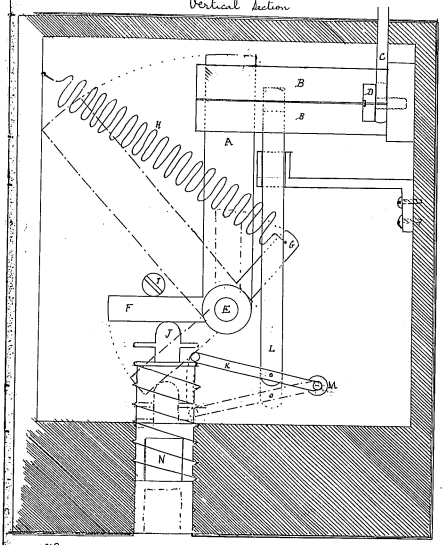
Vertical section
Parallel to axis Full size



Transformer circuit closed.

Design of an apparatus for disconnecting the transformer from the high-tension circuit by hand. Full size

Vertical section



The conducting blades A connected to the transformer are held by the double clips B.B. which are connected to the high tension circuit by the wires C under the screws D. The blades rotate in the vertical plane round the axis E and are in rigid connection with two arms F and G. The latter is pulled by the spiral spring H and the former is kept in check by the limiting stop I above and the point of the screw J beneath. This screw J is of coarse thread and of hard rubber. It carries in its motion the end of the lever K pivoted at M and bearing the vertical toggle L.

Three turns of the hard rubber screw which is rotated by a key inserted in the hollow N depress the screw J and lever K whose toggle during the last turn releases the detents on the end of B and allows the blades to fly back under the influence of the springs to the position shown in dotted lines. To close the circuit the screw is turned the opposite way forcing up the lever F until the detents close on the blades A.

The blades A are connected by straps to the washers of the screws O which communicate by wires with the transformer.

November 9th

Magnetic Experiment.

Two magnets were hastily wound as follows:-

Five plates of cast iron were selected each 20 x 20 x 1.27 (8"x8"x½") and four were superposed. Two ones were thus obtained one 5·1 cms and the other 1·27 cms thick. These ones were wound with one layer of tape. ~~The~~ Equal lengths of the same size wire (6300 cms of # 24 B.W.G silk covered 0.022" (0.056 cms) were then wound on so that the thick magnet had some 120 turns and the thin one about 140. They were then connected in series and about 3 ampères passed through them. No appreciable difference in their magnetic power could then be discovered by any rough method, such as the holding power, or the number of nails executed by a needle at a given distance, even when pole plates of the same breadth were laid on each.

Speculations on intermolecular distances and force.

1 lb. of gunpowder is stated to possess a total energy of about 500 ft lbs. Its specific gravity being about 1·8, 454 grammes occupy about 250 c.c. so that 1 c.c. has an energy of about 2 foot tons = 6.07×10^{10} ergs.

In one cubic centimetre of powder there may be some 10^{25} molecules at an average distance apart of $\frac{1}{200,000,000}$ centimetre.

Let us call this mean distance d

If we imagine all these molecules at rest and equidistant from each other the path from one to its nearest neighbor being d then it is quite possible that the atoms before explosion are maintained in somewhat unstable equilibrium at a distance from the inertia center of each molecule $< \frac{d}{2}$. Suppose we say $\frac{d}{4}$. This is the distance to which each half molecule (neglecting the chemical formula) would have to be moved after ignition in order to place the atoms beyond the range of their affinitive attractions. The force exerted in separation would probably have a steep gradient, but we may call the mean force f. Then

$$2 \times 10^{25} \times f \times \frac{1}{1,300,000,000} = 6.07 \times 10^{10}$$

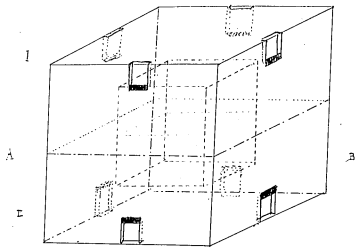
$$\therefore f = \frac{6.07 \times 10^{10} \times 1.8 \times 10^{9}}{2 \times 10^{25}}$$

$$= 5.5 \times 10^{-6} \text{ dynes}$$

$$= 5.5 \text{ microdynes.}$$

Trial of current strength necessary to properly operate a 1400 ω W.U. telegraph relay.

By means of a rheostat and the Siemens tangent (copper coil) galv: the current from 4 fuller cells was regulated till Mr Edison was satisfied with the relay operation. The res: was 350ω. $\frac{8}{350} = 0.020$ amp. The deflection 10·20° = 0.0214 so that 25 milliampères is a fair allowance, and 4 more cells for leakage say 40 at the battery end.



$\frac{r\,dr}{2\pi x}$ $\quad 2\pi \log e = \frac{2}{e}$

The heat generated in the ring is $2\pi x\,dx\,i^2\rho$ ohmwatts. The resistance beyond is $\frac{\sigma}{2\pi}\log_e\frac{A}{x}$

$$\frac{d^2v}{dx^2} = \frac{dv}{\frac{\sigma}{2\pi}\log_e\left(\frac{A}{x}\right)} = 2\pi x\,dx\,i^2\rho$$

$$\frac{dv}{dx} = i^2\rho\sigma\, x \log_e\left(\frac{A}{x}\right)$$

$$\frac{dv}{dx} = i^2\rho\sigma\, x \log_e\left(\frac{A}{x}\right) \qquad \left(x\log A - x\log x\right) \qquad \left(\log_e\left(\frac{A}{x}\right)\right)$$

$$v = i^2\rho\sigma\int x\log_e\left(\frac{A}{x}\right) \qquad x\log_e\frac{A}{x} = -\frac{A}{x}$$

$$= i^2\rho\sigma\left\{\left(\frac{x^2}{2}\log A\right) - \frac{2x^2}{2}\left(\log x - \frac{1}{2}\right)\right\} + B$$

$$= i^2\rho\sigma\left\{\log A\left(\frac{x^2}{2}\right) - \frac{A^2}{2}\log A - \frac{x^2}{2}\log x\right.$$

$$d\varphi = 2\pi x\,dx\,i^2\rho$$

$$\frac{d\varphi}{dx} = 2\pi x\,i^2\rho \qquad \varphi_1 = -\frac{2\pi x}{\sigma}\cdot\frac{dv}{dx} \qquad -\frac{dv}{dx}\,\frac{1}{\frac{\sigma}{2\pi x}}$$

$$\frac{dv}{dx} = \frac{\sigma\varphi_1}{-2\pi x}$$

$$\frac{d^2v}{dx^2} = \left(\frac{\sigma\frac{d\varphi}{dx}(+2\pi x) - 2\pi\sigma\varphi_1}{4\pi^2x^2}\right) \qquad \frac{d^2v}{dx^2} = \frac{\sigma\frac{d\varphi}{dx}}{-2\pi x} = i^2\rho\sigma$$

$$-\frac{\sigma i^2 2\pi^2x^2 + 2\pi\sigma\varphi_1}{4\pi^2x^2}$$

$$2\pi\sigma\,0$$

$$\frac{dv}{dx} = i^2\rho\sigma\, x + a$$

$$v = i^2\rho\sigma\frac{x^2}{2} + ax + b$$

When $x = X$ $\quad v = 0$ $\qquad 0 = i^2\rho\sigma X^2 \qquad b = 0$

$$v = i^2\rho\sigma\frac{x^2}{2} + ax$$

$x = X$ $\quad v = V$ $\qquad V = i^2\rho\sigma\frac{X^2}{2} + aX$

$$a = \frac{V}{X} - \frac{i^2\rho\sigma X}{2}$$

$$v = i^2\rho\sigma\frac{x^2}{2} + \frac{Vx}{X} - \frac{i^2\rho\sigma X^2}{2}$$

$$\frac{i^2\rho\sigma}{2}\left(X^2 - x^2\right) + \frac{Vx}{X}$$

$$\frac{1}{2}\frac{d\Psi}{dx} = \frac{1}{2}\frac{d\Phi}{dx}$$

$$\frac{d\Phi}{dx} = 2\frac{d\Psi}{dx}$$

$$d\psi_2 = i^2\rho\, 2\pi x\, dx \qquad d\phi_2 = i^2\rho\, 2\pi x$$

$$\phi_2 = -\frac{2\pi x}{\sigma}\frac{dt}{dx}$$

$$\therefore \frac{dt}{dx} = -\phi_2\frac{\sigma}{2\pi x}$$

$$\frac{d\Psi}{dx} = -d\psi_2\frac{\sigma}{2\pi x} + \phi_2\frac{\sigma}{2\pi x^2}$$

$$\frac{d\Psi}{dx} = -i^2\rho\sigma - \frac{2\pi x}{\sigma}\frac{dt}{dx}\frac{\sigma}{2\pi x^2}$$

$$= -i^2\rho\sigma - \frac{1}{x}\frac{dt}{dx}$$

$$\frac{d\Psi}{dx} = \frac{1}{x}\frac{dt}{dx} - i^2\rho\sigma$$

$$x\frac{d\Psi}{dx} = \frac{dt}{dx} - i^2\rho\sigma x$$

$$x\frac{d\Psi}{dx} = -i^2\rho\sigma x^2 + x$$

$$\frac{dt}{dx} = -\frac{i^2\rho\sigma x}{2} + \frac{\sigma}{x}$$

$$t = -\frac{i^2\rho\sigma x^2}{4} + \alpha\log x + b$$

If $x = X$ $\quad t = T$ $\qquad T = -\frac{i^2\rho\sigma X^2}{4} + \alpha\log X + b$

$x = 0$ $\quad t = 0$ $\qquad 0 = \alpha\log 0 + b$

$$\frac{dt}{dx} = -\frac{i^2\rho\sigma x}{2} + \frac{\sigma}{x}$$

$$t = -\frac{i^2\rho\sigma x^2}{4} + \alpha\log x$$

Experiment on the direction of electromagnetic stress in magnetized iron

November 11th. An iron box cast at the Phonograph factory in the former of an almost entire rectangular parallelopiped was prepared in two halves capable of being united by two screw lugs.

The box completed was 6.1 cms long 6.1 cms broad and 6.5 cms deep externally. In the interior it was nearly 3.8 " " 3.8 " " " 3.8 " so that the thickness of the walls were about 1.4 cm at every point. Four holes [] were cut in each half 1 cm × 0.25 cm. with external and internal grooves to assist winding.

The sides of the box were then wound with silk covered copper wire 0.016" and 0.020" over a single thickness of paper.

On side #1 the coil at right angles to the line AB had 30 turns (a)
" " 1 " " parallel " " " " 30 " (b)
" " 2 " " " " " " " 30 " (c)
" " 2 " at right angles " " " " 30 " (d)

The inductances of the two coils on side 1 were measured, first with the cube on the table, second on between the poles of the large unexcited electromagnet, and third between those poles when the magnet was excited. The faces A and B were in contact with the pole, so that the magnetic flux was ∥ to (b) and ⊥ (a). If then the magnetic strain allowed freedom of molecular motion at right angles to the stress, then the inductance of (b) should not be reduced while that of (a) would reduce owing to saturation. The actual results obtained as shewn in the following table make it evident that the reluctances were nearly equal — and allowing for the reduction of flux due to the slit perhaps quite equal — in both directions, so that if iron is magnetized in such a way that its reluctance increases in the direction of the flux it increases equally or nearly equally in other directions.

No.	Bridge	Resp. of coil, Ohms	Resp. for self balance	Inductance quadrants	Inductance Henries	Position of cube.	Coil tested		
1	1000/1	3.761	0.400	0.00150	15.02	on table	(a)		
2	"	3.740	"	0.00189	14.96	" "	(b)		
3	"	3.720	0.450	0.00168	16.89	Between pole unexcited	(b)		
4	"	3.757	0.430	0.00162	16.16		(a)		
5	"	3.758	0.030	0.00018	1.128	Between poles strong excitation abt 12 amp.	(a)		
6	"	3.726	0.077	0.00029	2.870		(b)		
7	"	3.727	0.147	0.00055	5.476	Between poles Mild excitation abt 0.5 amp.	(b)		
8	"	3.757	0.072	0.00027	2.705		(a)		
	T.B. 2430								

Tests of a certain material named Vulcabestos made for Mr Insull.

Received various samples of this insulating material on 1st November. It has a very fibrous structure, and appears to be a pressed combination of asbestos, rubber, and sulphur.

In the lathe it was found to burn the edge of the cutting tool nearly as badly as hard rubber, and also to take a very rough surface so that it becomes necessary to press it in order to obtain a smooth face.

It burns with difficulty and giving an odor of burnt rubber.
It was attacked strongly by HNO_3
" " " " H_2SO_4 leaving asbestos residue after washing
amounting to about 20% by weight.
Not affected chemically by H_2O but absorbs fairly.
Slightly soluble in CS_2. (about 10% by cover)
Not affected by NH_4O, $C_{10}H_{16}$, naphtha, paraffine oil or spermit in one days trial.

To determine the winding of a phonoplex coil to have 114 ohms res, and 3410 turns, over a diameter of 0.813".

Let x be the ~~diam~~ diam. of the wire in ~~cmil~~ mils
x^2 " " area - - - circ. mils
c " " covering in mils
$(x+2c)^2$ " " area of wire in circ. mils.
Let L - - length of the coil in mils
Then $\frac{L}{x+2c}$ = no. of turns in the layer.
with n layers, the no. of turns = $\frac{nL}{x+2c}$.
The diam of the mean turn will be $d + n(x+2c)$ mils
The length of the mean " " " $\pi\{d + n(x+2c)\}$ mils.
" total length = $\frac{\pi n L}{x+2c}\{d + n(x+2c)\}$ mils

The res. of this length = $\frac{\pi n L}{x+2c}\{d + n(x+2c)\} \times \frac{10}{12{,}000} \times \frac{1}{(x)^2}$

The data are $\frac{nL}{x+2c} = 3410$ $\therefore n = \frac{3410(x+2c)}{L} = \frac{3410(x+2c)}{3900}$

and $\frac{3410\,0\pi}{12{,}000\,x^2}\{d + n(x+2c)\} = 114$

$$107{,}200\{850 + 0.875(x+2c)^2\} = 16800x^2$$
$$(850 + 0.875x^2 + 2.1x + 1.039)$$
$$107{,}200(0.875x^2 + 21x + 1.039) = 16800x^2$$
$$93700x^2 + 2{,}250{,}000x + 1{,}168{,}000 = 16800x^2$$
$$76900x^2 + 2250000x = -1{,}168{,}000$$
$$x^2 + 29.26x = -1.90$$
$$x^2 + 29.26x + 214 = -887.6$$
$$x + 14.6 = \mp 29.0$$
$$x = 43.6$$

#19 BWG 0.042"

$3900 \div 54 = 72$ turns = 47 layers, mean diam = $2.54 + 0.81 = 3.35$"
$= 0.28$ feet circ. $\times 3410$ turns = 3000 feet @ 0.00585 = 17.55.

Next size BWG #18 0.049" = 0.061" cond = 60 turns per layer = 57 layers.
Mean diam $0.813 + 3.48" = 4.29" = 0.3575$ ft $= 1.123$ ft @ $\times 3410$ turns = 3830 ft.
@ 0.0043 = 16.5 w.

Next 2 sizes BWG #16 0.065 = 0.077" cond = 50 turns per layer = 68 layers
Mean diam $= 0.813 + 5.24 = 6.05" = 0.504$ ft $= 1.58$ ft @ $\times 3410$ turns = 5400 ft
@ 2.44×10^{-3} = 13 w.

#17 next size.

#17 BWG = 0.058" = 0.070" cond. 55 turns per layer = 62 layers
Mean turn = $0.81 + 6.24 = 5.15" = 0.43'$ = 135 ft per turn @ 3410 turns = 4600 ft
@ 3.07×10^{-3} = 14.140

62 layers of 55 turns each #17 BWG 0.058" cond to 0.070"

Comparison of inductance between an ordinary phonoplex induction coil, and three experimental bobbins

Phonoplex coil length between flanges 10 cm. Diam: of wire over 1·2 diameter of hard rubber cylinder over core 1·42. Diam: over braiding 3·5 19 layers of 18# turns # 23 wire B.W.G. 0·025" cond to 0·030".

Bridge	Res:	Capy:	Inductance Quadrant	Kilometer	T.B.
1000/1000	7.187	1.71 †	0·1229	1229	

3 coils of same size wire, uncovered wound over iron wire on periphery of wooden solid cylinder. Diam: over wire 12·8 + breadth between flanges 9·85 120 turns of wire in a single layer.

No.	Bridge	Res:	Capy	Inductance Quadrant	Kilometer	T.B.	Position of coil	Average Kilometer per coil
1	1000/10	8·347	1.130	0·00944	94·3			31·4
2		8·352	1·335	0·0715	115·			38·3
3		8·359	0·918	0·00767	76·7			25·6
4		2.832	1·098	0·0031	31·1		One coil above removed from other	31·1

To find the number of # 35 B.W.G. that must be stranded to make the equivalent of a # 23 wire.

35 = 0·005" = 25 c.mils.
23 = 0·025" = 625 " " equivalent to 25 # 35s.

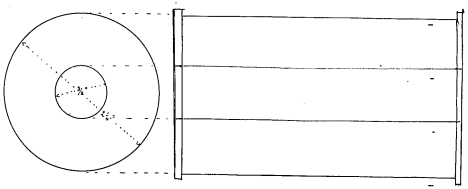
420 feet of # 23 = 10500 feet of # 35. in all.

On the winding of a phonoplex magnet required to have the maximum discharge with swiftness.

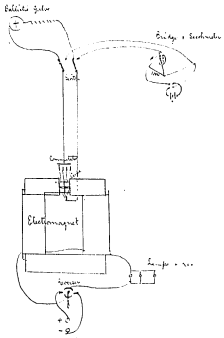
The discharge value of a coil apparently depends upon $\frac{L}{R}$ and this is independent of the length but varies with the square of the diameter of the iron core so long as the field in the latter is maintained sensibly uniform. To force more current into the present coil of 7·4 res: and 1·5 amp: is to over-heat, for its wire surface is now about 110 sq. cm. and the Watts 16 = 7·4 cm per Watt. We may therefore take the existing length of coil, increase the diam: of core to 0·75" and the ext: diam: to 2·5". Throw with 12 Nat-Hol cells @ 1·5 amperes. The res: of the cells (phonoplex type) 0·03 each = 0·36 ω and the coil 5·24 ω. The ext: diam: over rubber will be 2·05 cm. and the exterior of core 6·35 so that the coiling space = 0·7854 × 10 × (40·32 − 16·20) = 7·854 × 36·12 = 283·7 c.c.

$$\therefore d = -\frac{b}{2} \pm \sqrt{\left\{0.0004 + 0.00153\sqrt{\frac{283.7}{5.1}}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153\sqrt{55.64}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153 \times 7.46\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.01142\right\}}$$
$$= 0.01 \pm \sqrt{0.01182} = \pm \cdot 1087$$
$$= 0.099 \text{ cm.}$$
$$= 0.039''$$

nearest = # 19 B.W.G. 0·042" cond to 0·052" × 5·10 = 872 feet; 75 turns per layer
Mean layer 0·433 fr circum. 32 feet in layer = 29 layers

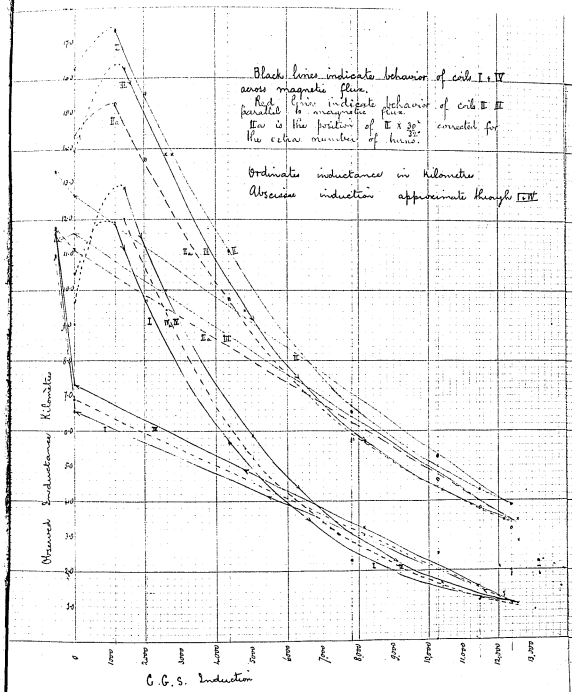


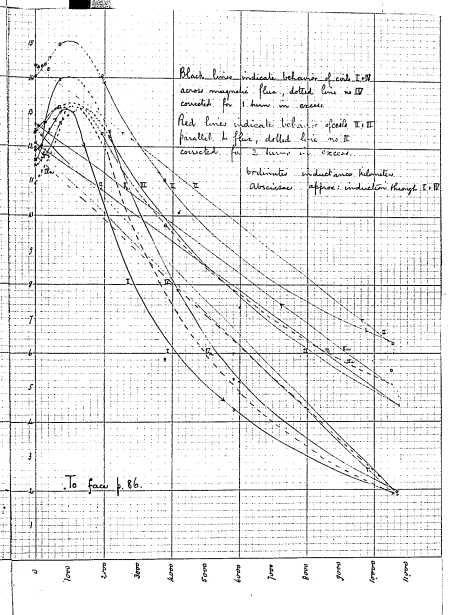
#20 B.W.G = 0·035" 0·045" cond = 85 turns per layer
= 600 feet = 16½ layers



gb·3 dis represent $1{\cdot}4224 \times 10^{8} \times 1{\cdot}0 \times 10^{-15}$ gr. = $1{\cdot}4224 \times 10^{-7}$
1 - represents $1{\cdot}4278 \times 10^{-7}$

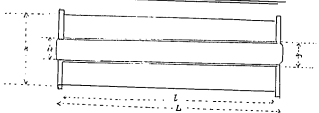
n - thus $5{\cdot}270 \times 10^{14} \times 1{\cdot}4278 \times 10^{-7} = 7{\cdot}788 \times 10^{7}$ bris
+ $1{\cdot}527 \times 10^{13} \times 1{\cdot}4278 \times 10^{-7} = 2{\cdot}257 \times 10^{6}$


Black lines indicate behavior of coils I + IV across magnetic flux.
Red lines indicate behavior of coils II + III parallel to magnetic flux.
Here is the position of II x 90° corrected for the extra number of turns.
Ordinates inductances in kilometers
Abscissae induction approximate through I + IV
Measured Inductance Kilometers
C.G.S. Induction


Black lines indicate behavior of coils I + IV across magnetic flux, dotted line no IV corrected for 1 turn in excess.
Red lines indicate behavior of coils II + III parallel to flux, dotted line no II corrected for 2 turns in excess.
Ordinates inductance kilometers
Abscissae approx: induction through I + IV

To face p. 86.

Inductance Measurements.



Bridge 1000/1000 T.B. 26.3.10

No.	Description	Dimensions L	l	x	y	z	diam. of outer	diam. of inner	zero correc.	Res. including bar w	Coil Res. at 0°C ρ	Inductance Quadrant	Reluctance	Res. @ 24°C w	Inductance Corrected $\frac{L}{R}$ Seconds
1	Phosphor	10·9	9·9	3·9	1·115	1·25	0·025	0·030	0·025"	7·16	1·82	0·1303	1303	7·05	0·0185
2	"	10·9	9·9	3·9	1·14	1·15	0·025	0·030	0·025	7·415	1·775	0·1317	1317	7·305	0·0180
3	steel	11·0	10·1	3·75	1·3	1·2	0·025	0·030	0·015	5·592	1·140	0·0638	637·7	5·42	0·0116
4	Phosphor	10·5	9·8	3·75	1·55	1·3	0·025	0·030	0·025	7·224	1·830	0·1322	1322	7·114	0·0186
5	Phosphor recent							1000/1000	Front face	104·755	1·60	0·1676	1676	104·644	0·00153
									Back "		1·93	0·2022	2022	104·644	0·00193

Experiment with iron cube on the direct scale of reluctance in magnetised iron

Nov. 14th

Cube placed between poles of electromagnet and following obs. taken.

No. Expt.	Bridge	Coil tested	Res. of coil & cable	Coil by Wheat	Inductance Reluctance	Adjustment of quadrant to correct for reluctance	Number of magnetic Ballistic	Galv.	Mean Phase	Res. of galv. at	ρ	Adjustment cable and by coil	L	μ	Mean μ
1	comp.	1	2·198	0·360	10·43	0						270			
		2	2·969	0·550	12·33	10·34						260·3			
		3	2·853	0·490	13·98							245·7			
		4	2·930	0·330	9·17	7·20						271·4			
2		1	2·897	0·410	11·89	0·1 amp	82	93	92·5		6·44×10⁻⁶	318 mm	1190		
		2	2·968	1·585	17·36	15·16						1b			
		3	2·854	0·570	16·27							30	1350		
		4	2·927	0·440	12·28	11·05						31			
3		1	2·899	0·255	9·77	0·17 amp	143	143	143		7·88×10⁻⁶		1470		
		2	2·967	0·225	10·38						1·16×10⁻⁶		2060		
		3	2·856	0·485	13·83										
		4	2·926	0·340	9·95								2350		
4		1	2·898	0·195	5·24	0·28	105	102	104	8270	1·48×10⁻⁶		2890		
		2	2·965	0·375	11·12						2·38×10⁻⁶		4350		
		3	2·848	0·320	9·40										
		4	2·925	0·200	5·85								4910		
5		1	2·900	0·220	2·55	0·5	187	188	187·5		2·61×10⁻⁶		7836		
		2	2·973	0·220	6·54						4·32×10⁻⁶				
		3	2·855	0·200	5·71										
		4	2·928	0·110	3·29										
6		1	2·900	0·075	2·17	1·0	244	244	245		5·52×10⁻⁶		10240		
		2	2·973	0·075	2·25										
		3	2·866	0·150	4·34										
		4	2·940	0·055	1·62										
7		1	2·899	0·040	1·16	1·5	275	275	275		6·20×10⁻⁶		11490		
		2	2·976	0·065	1·91										
		3	2·868	0·120	3·42										
		4	2·922	0·065	1·92										
8		1	2·899	0·025	1·00	10 amp	298	295	296·5		6·69×10⁻⁶		13,100		
		2	2·978	0·025	3·86										
		3	2·858	0·100	2·85										
		4	2·921	0·025	1·02										
9		1	2·900	0·227	0·658	0	295	310	302·5		6·92×10⁻⁶		12,550		
		2	2·974	0·227	1·270										
		3	2·858	0·207	1·160										
		4	2·924	0·200	0·734										
10		1	2·902	0·400	11·61										
		2	2·974	0·450	12·38										
		3	2·858	0·400	11·43										
		4	2·924	0·400	11·73										

1 Ohm at temp 28°C. thus galv. = 1 ρ = 96·3 mean phase

The excess of induction through 4½ over 1 is partially due to the fact that 1 & 2 were above 3 & 4 bench & that the pole faces slightly approached downwards letting the cube rest slightly wedged below.

Red figures are values of ρ corrected for extra 1 turns

1 16 c.p. burner vitiates the air to the same degree as five persons

1 c.p. gas vitiates equivalent to 0.312 persons.

1 c.f. - burnt per hour - - 1 -

A room 30 ft square = 900 sq. feet = 836100 sq. cms.

its candle power n = $8.36 \times 10^5 \times 3.12 \times 10^{-4}$ = 261 c.p. brilliant (it would be moderately) lighted by one third of this = 87 c.p. say 5 jets of 16 c.p.

Its volume would be 135000 c.f. = $1.35 \times 10^8 \times 2.83 \times 10^{-4}$ c.c.

= 3.82×10^7

80 c.p. raise 5600,000 c.c. of gas air 1°C. per sec.

10,080,000 - - - - 1°F - -

- - - 3,360,000 - - - - 30°F - -

$\frac{3.82 \times 10^7}{3.36 \times 10^6}$ = 11.37 seconds for the whole room.

= 19 mins.

Problem: A room of given dimensions is lighted by gas in sufficient abundance for good illumination. Required the temperature of the room after a given interval and also the corresponding temperature with incandescent lamp equivalent illumination.

Let V be the volume of the room (c.c.)

a its area (sq.cms)

h its height (cms)

Then allowing Preece's rule of 1 Watt per 1000 sq. cms. (10 Watts per sq. metre) of floor space = 0.001 Watt per sq cm

so that if W be the Watts required

$W = 0.001\,a$

and the total illumination in c.p. will be $\frac{W}{3.2} = 0.000312\,a$.

so that if n be the number of candles required

$n = 0.000312\,a$

For 16 candles power the average volume of gas consumed is 5 c.f.

so that for 1 c.p. 0.312 c.f. of gas are consumed per hour

for n = $0.000097735\,a$ c.f.

1 c.f. of gas produces in combustion 850 B.T.U. units

$= 8.50 \times 1.058 \times 10^{10}$ ergs

$= \frac{8.50 \times 1.058 \times 10^{7}}{4.2}$ gramme calories (therms)

$= 2.14 \times 10^{6}$ therms.

1 c.f. in gas $= 6.68 \times 10^{4}$ therms per hour

= 1113 - - mins

= 18.5 - - second.

1 c.p. in an Edison lamp takes 3.2 Watts

= 0.762 therms per sec.

= 45.7 - - mins.

so that 1 c.p. in gas gives 24 times as much heat as 1 c.p. of incandescence.

The specific heat of air being 0.238 one therm will raise 4.2 grammes of air 1°C. or 1 Watt will raise 1 c.c. of air 1°C. per sec.

and 1 gramme of air occupies 784 c.c. @ 0°C or $784\left(\frac{313}{273}\right) = 900$ c.c. @ 30° C. consequently each candle power of incandescence raises 2880 c.c. of air 1°C.

- gas. " 70000 - - -

consequently n c.p. in gas raise $70,000\,n$ c.c. of air 1°C. per sec.

n - - incandescence - $2900\,n$ - - - - - -

∴ the whole volume of the room being abh

the air in it will be raised 1°C. in $\frac{abh}{70,000\,n}$ seconds by gas

and $\frac{abh}{2900\,n}$ - - incandescence

substituting for n $3.12 \times 10^{-4}\,a$

the room will be raised 1°C in $\frac{h}{70 \times 10^{3} \times 3.12 \times 10^{-4}}$ seconds by gas

and $\frac{h}{2.9 \times 3.12 \times 10^{-1}}$ - - incandescence

$= h/21.84$ by gas and $10\,h/9.05$ by incandescence

$= 0.046\,h$ seconds - - $1.105\,h$ seconds - -

A room 15 feet high = 4500 cms. would be raised 1°C in 206 seconds by gas

- 4980 - - mins

Experiment with iron cube on the Direction of Reluctance in magnetised iron.

November 15th Rules placed between poles but separated on each side by square sheets of hard rubber 0·2(5 in) thick, and following obs. taken.

Date	Bridge	Block Board and Rule	Rim. Ohms of coil & lead	Ratio for balance R	Induc. Henries	approx. C in c.m. sec. amp	Throw of Ballistic Galv. +	−	Mean Ballistic throw	Rim in Galvanom.	φ	approx. mean φ	L	μ	mean μ
1	100 cycl.	1	2·902	0·415	12·05							270			
		2	2·983	0·473	12·11	0·11						264·3		III	11·96
		3	2·881	0·400	11·52							245·7			
		4	2·984	0·400	11·62	0·98						274·9		IV	11·47
2		1	2·903	0·405	11·76							30			
		2	2·983	0·467	13·93	0·05 0						30		III	11·89
		3	2·890	0·400	11·52							30			
		4	2·984	0·400	11·63	0·94						31		IV	11·33
3		1	2·907	0·410	11·92							102·9			
		2	2·984	0·480	14·32	0·07	+5	7	3	5270	2·77 x10⁻⁶	102		III	12·07
		3	2·885	0·400	11·54										
		4	2·986	0·480	11·95	0·19	8	9	3		2·77 x10⁻⁶	102·2		IV	11·56
4		1	2·907	0·420	12·21	0·08	9	11	4·8		4·44 x10⁻⁶	164·6			
		2	2·988	0·480	14·34	0·10						167		III	12·07
		3	2·886	0·400	11·54										
		4	2·911	0·400	11·62	0·19	7	8	3·8		3·21 x10⁻⁶	129·4		IV	11·70
5		1	2·908	0·425	12·36	0·09	8	9	4·3		3·99 x10⁻⁶	147·6			
		2	2·989	0·480	14·34	0·10						136·6		III	12·07
		3	2·886	0·400	11·54										
		4	2·912	0·415	12·09	0·33	7	9	4·0		3·70 x10⁻⁶	128·4		IV	11·85
6		1	2·907	0·425	12·36	0·11	11	12	5·8		5·39 x10⁻⁶	198·9			
		2	2·989	0·480	14·34	0·10						199·3		III	12·15
		3	2·886	0·415	11·69										
		4	2·912	0·415	12·09	0·33	11	12·5	5·9		5·46 x10⁻⁶	200·9		IV	11·95
7		1	2·912	0·430	12·53	0·14	18	16	7·3		6·57 x10⁻⁶	243·7			
		2	2·994	0·480	14·38	0·10						248·8		III	12·23
		3	2·887	0·400	11·53										
		4	2·916	0·435	12·69	0·34	13	16	7·3		6·57 x10⁻⁶	246·9		IV	12·21
8		1	2·911	0·425	12·38	0·18	22	24	11·8		10·65 x10⁻⁶	394·5			
		2	2·992	0·475	14·23	0·51						395·1		III	12·11
		3	2·891	0·400	11·71										
		4	2·915	0·427	12·45	0·16	23	24	11·8		10·93 x10⁻⁶	401·7		IV	12·00
9		1	2·909	0·447	13·01	0·25	43	44	21·8		20·19 x10⁻⁶	747·5			
		2	2·988	0·500	14·94	0·14						752·8		III	12·93
		3	2·888	0·440	12·71										
		4	2·913	0·480	13·99	0·34	43	46	22·3		20·63 x10⁻⁶	758·2		IV	13·01
10		1	2·910	0·370	10·77	0·50	104	109	52·3		50·27 x10⁻⁶	1862			
		2	2·988	0·470	14·05	0·35						2063		III	12·31
		3	2·887	0·425	12·27										
		4	2·913	0·427	12·44	0·45	126	124	63		5·53 x10⁻⁶	2166		IV	11·21
11		1	2·910	0·300	9·82	1·0	219	221	110		1·08 x10⁻⁶	3771			
		2	2·989	0·370	11·26	0·75						3916		III	9·91
		3	2·886	0·350	10·10										
		4	2·911	0·370	7·96	0·76	244	241	122		1·12 x10⁻⁶	4152		IV	6·53
12		1	2·910	0·150	4·36	2·0	116	118	58·5	10000 + 5270 = 15270	1·05 x10⁻⁶	5812			
		2	2·989	0·200	5·976	1·5						5905		III	6·31
		3	2·886	0·255	7·323										
		4	2·911	0·170	4·950	2·4	120	123	60·5		1·63 x10⁻⁶	5997		IV	4·50
13		1	2·913	0·165	4·894	2·0	224	220	106		2·43 x10⁻⁶	16·530			
		2	2·990	0·210	6·174	1·5	0					16·65		III	5·80
		3	2·886	0·155	4·472		0								
		4	2·912	0·170	4·888	2·4	213	221	108·5		2·41 x10⁻⁶	16·700		IV	4·96
14		1	2·910	0·410	11·93	0									
		2	2·990	0·480	14·35	0·13								III	12·38
		3	2·885	0·420	12·13										
		4	2·913	0·420	12·53	0·34								IV	11·84

1 Block all 23·5°C 1 before test mean throw 81·8 after test 81·0 mean 81·4

81·4 divs represent $1·430 \times 10^{7} \times 1·0 \times 10^{-16} = 1·430 \times 10^{-7}$ abs qp

1 - - $1·756 \times 10^{-7}$ - -

d - - $1·756\ d \times 5·270 \times 10^{3} = 9·256 \times 10^{3}$ lines

and $1·756\ d \times 1·927 \times 10^{3} = 2·652 \times 10^{3}$ -

Res. of each end of Galv. 2690 Res. unit 0.02452

No. in ½	Time	Mean Thermo Rdg	Mean amperes	Res. in cst. unit	Total res. in cst. unit	Res. of ½	R/r	Rise of temp °C	C°	Rad. per cm.	Energy per cm.	Radiation per cm.	Radiation per cm.	Temp. air
1	20.00/50	0.0132	1.08	4420	7110	0.06555				0.000178				25.2°C
	22.00/50	0.067	5.46	4525	7215	0.0658	1.0125	3.22	29.81	0.000104	0.001262	0.001362		26°C
	24.00/21.00	0.2655	21.65	5550	8240	0.0754	1.156	4.02	468.7	0.000125	0.001760	0.07026		
	21.00/15	0.5140	41.93	9125	11815	0.1077	1.657	169.4	1758	0.000791	0.03119	0.2465		
	15	0.013	1.08	4450	7140	0.06572				0.000-1013				26.5°
2	20.00/50	0.067	5.46	5780	8470	7792			29.81	1.307				25.2
	22.00/21.00	0.2655	21.65	7890	10470	7792			468.7	1.307				
	24.00/15	0.5144	41.93	5665	8245	7.945	1.019	4.9	1758	1.333	0.02343	0.00585	0.01758	
	15	0.013	1.08	5750	8440	7.918			1	—				
	20.00/50	0.777	63.36	5290	7980	8.270	1.0408	15.6	4.01×10³	1.387	0.0587	0.0273	0.0463	
	22.00/50	0.891	72.66	5160	7850	8.406	1.078	20.1	5.220	1.440	0.0744	0.0352	0.02986	
	24.00/50	1.076	87.72	4805	7495	8.806	1.129	33.3	7.695	1.477	0.1137	0.05829	0.0565	
	26.00	1.166	95.05	4610	7300	9.040	1.159	41.0	9.034	1.516	0.1370	0.07176	0.07194	27.2°
3	20.00/50	0.067	5.46	1070	3760	1.7550			29.81	3.018×10⁻⁴				
	22.00/50	0.2655	21.65	982	3672	1.797	1.024	6.2	468.7×10⁻⁴	3.087	0.01447			25.2
	24.00/15	0.514	41.93	782	3472	1.929	1.099	25.5	1.758×10⁻³	3.314	0.05927			
	15	0.013	1.08	1070	3760	1.755	—		1.06					
	20.00/50	0.777	63.36	349	2039	2.172	1.238	61.4	4.01×10⁻³	3.731	0.1498			
	22.00/50	0.891	72.66	195	2885	2.316	1.320	82.5	5.220	3.979	0.2101			
	24.00/50	1.076	87.72	130	2880	2.627	1.497	128.1	7.695	4.513	0.34714			
	26.00	1.166	95.05	375	3065	2.776	1.582	150.0	9.034	4.809	0.4305			27.2
4	20.00/50	0.067	5.46	3050	5740	1.15×10			2.981×10⁻³	1.04×10⁻³				
	22.00/50	0.2655	21.65	2990	5680	1.162	1.006	1.5	4.687×10⁻³	1.046	0.00981			25.2
	24.00/15	0.514	41.93	3350					1.758×10⁻³					
	15	0.013	1.08	3000	5690	1.160	1.005	1.5	1.16					
	20.00/50	0.777	63.36	2400	5090	1.297	1.123	31.7	4.01×10⁻³	2.217	0.0703			
	22.00/50	0.891	72.66	2230	4920	1.341	1.161	41.5	5.220	2.292	0.12.10			
	24.00/50	1.076	87.72	1900	3590	1.838	1.590	132.6	7.695	3.112	0.2419			
	26.00	1.166	95.05	1700	3390	1.947	1.656	176.4	9.034	3.329	0.3098			27.2

Experiment on the Radiation of heat from wires carrying currents as a function of their absolute temperature 16th November 89.

(91)

Four bare bright copper wires were suspended across the room as in the experiment detailed at the commencement of this book. They were connected in series and their resistances measured by comparison with the grid after passing different current strengths through them for two or three minutes; the temperature of the air near the wires and probably the mean temperature of floor walls, objects + ceiling rising from 25° to 27°C. These measurements having been taken the steam was cut off the building; all windows and doors widely opened and air allowed to circulate through the building for 30 minutes the external temperature being 0°C. The windows were again closed and the measurements repeated as speedily as possible the temperature rising from 8° to 15°C. The following were the results obtained.

No. of wire	Length Metals	Diameter Diam.	Area Cir. mils	Sq. cms.	Surface per cm. sq. cms.	Res. per cm. to 25°C	Resistance per cm. to 0°C	Resistivity	Conductivity $\frac{1}{\rho}$
1	601.5	0.057	0.1448	3,250	0.01647	0.06549	0.0001078	0.0000925 e.g. 1×10^{-6}	1618
2	576.3	0.1645	0.418	27,600	0.1372	0.13130	1.307×10^{-5}	1.192×10^{-5}	1635
3	582.2	0.108	0.2743	11,640	0.05910	0.8616	3.018×10^{-5}	2.728×10^{-5}	1625
4	585	0.134	0.34024	17,960	0.09102	1.0697	1.966×10^{-5}	1.792×10^{-5}	1631

No. in ½	Time	Mean Thermo Rdg	Mean amperes	Res. in cst. unit	Total res. in cst. unit	Res. of ½	R/r	Rise of temp °C	C°	Rad. per cm.	Energy per cm.		
1	22.00/50	0.0135	1.09	4020	6670								
	24.00/50	0.2619	21.35	5090	7740								
	26.00/21.00	0.5323	43.89	5570	8220								
	21.00/15	0.7385	60.22										
	15	0.0856	8.4.44										
	20.00	1.142	93.10										
	22.00	0.0212	2	4100	6750								
2	22.00/50	0.0135	1.1	6110	8760	7.420							
	24.00/50	0.2619	21.35	6150	8800								
	26.00/21.00	0.5382	43.89	5900	8550								
	21.00/15	0.7385	60.22	5140	8140								
	15	0.0856	8.4.44	5160	7810								
	20.00	1.1142	93.10	4860	7510	8.656	1.1656	20.1					
	22.00	0.0216	2	5370	8620	7.542	2	25.77					
3	22.00/50	0.0135	1.1	1250	3900								
	24.00/50	0.2619	21.35	1160	3810								
	26.00/21.00	0.5382	43.89	855	3505								
	21.00/15	0.7385	60.22	380	3030								
	15	0.0856	8.4.44	-65	2495								
	20.00	1.142	93.10	-235	2295								
	22.00	0.024	2	1180	3820								
4	22.00/50	0.0135	1.1	3300	5950								
	24.00/50	0.2619	21.35	3210	5860								
	26.00/21.00	0.5382	43.89	3000	5650								
	21.00/15	0.7385	60.22	2510	5160								
	15	0.0856	8.4.44	2115	4760								
	20.00	1.1142	93.10	1940	4590								
	22.00	0.022	2	3150	5800								

Speculations on the dimensions of electrical quantities, and on the nature of electrical action.

Since electricity can have one and only one nature, it is necessarily untrue that the dimensions of any electrical quantity say current can be different according to the system of units by which it is measured, and Professor Rücker has shown that the ratio v between the electrostatic and electromagnetic units problably arises from ignoring the dimensions of κ and μ.

Although the quantity of electricity can hardly be of the nature of a mass since it does not appear to be a function of gravitation, it must be in all probability directly connected with a mass, for all forms of energy seem to be mass-movement. Thus it should be independent of time. For example it might resemble a wheel capable of delivering and manifesting energy by changes in its motion, and to complete the analogy its dimensional expression might be that of moment of mass ML. If this hypothesis be accepted we have from the fundamental statical equation $f = \frac{q^2}{\kappa d^2}$

$$q = f^{\frac{1}{2}} \kappa^{\frac{1}{2}} d = ML$$
$$= L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1} L \kappa^{\frac{1}{2}} = L^{\frac{3}{2}} M^{\frac{1}{2}} T^{-1} \kappa^{\frac{1}{2}}$$
$$\therefore \kappa = L^{-1} M T^{2}$$
$$c = q/t = ML T^{-1} = \text{mass motion, \& absolute or relative}$$
$$\varepsilon = w/q = ML^{4} T^{-2} L^{-\frac{3}{2}} M^{\frac{1}{2}} T^{-1} \kappa^{\frac{1}{2}} =$$
$$= A_{\mu} T^{-2} = \text{acceleration in angular velocity.}$$
$$r = \varepsilon/c = T^{-2} M^{-1} L^{-1} T$$
$$= L^{-1} M^{-1} T^{-1}$$
$$s = \frac{q\kappa}{\varepsilon} = ML L^{-1} M T^{2} T^{2}$$
$$= M^{2} T^{4}$$

A current on this supposition has the nature of momentum, while an electromotive force has an acceleration in angular velocity, resistance, electrostatic capacity, and permittivity are meaningless.

Also since $\frac{1}{2}\mu c^2 = L^2 M T^{-2}$ and $c^2 = M^2 L^2 T^{-2}$

$$\mu = M^{-1}$$

and also since $\frac{1}{\sqrt{\kappa\mu}} = \frac{L}{T}$

$$\kappa = L^{-1} M^{-1}$$
$$\therefore \mathcal{L} = L$$

so that the inductance is still a length, but should always be multiplied by the reciprocal of a mass, which, combined with the square of current it becomes energy.

Measurement of the electrochemical equivalent of zinc.

23. X. 89 to 30. X. 89. Observer Schmalen

Two small meter bottles set up with plates 0.62 × 2.5 × 3.76 cm amalgamated but in solution of pure $ZnSO_4$. 1.054 drops acid.

No. of Obs.	Weight after heat	Weight after heat	Difference Gain	Weight Loss	Time elapsed	Mean current	Mean density of C.	Mean transfer	Electrochemical equivalent	Atomic Wt. of Zinc.
1	49.4048	48.8116		0 - .5932						
2	47.7114	48.2056	0.5942	.5942 (0)				0.5950	0.3246 × 10⁻²	62.46
3	49.6139	50.2097	0.5958	.5958 (0)						
4	48.4023	47.8068		0 - .5955				2.0515		
5	11.9751	12.9239		2.0512						
6	16.9780	19.0298	2.0518							

Keeping 38 amperes (divided among) 28 spools at 110 volts all in series gives 2.900 ω for the whole circuit = 0.1036 ω for each spool.
Will the value

$$d = -0.01 \pm \sqrt{\left\{0.0004 + 0.00153\sqrt{\frac{2170}{0.1036}}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153\sqrt{20940}\right\}}$$
$$+ 0.00153 \times 144.7\}$$
$$+ 0.2214$$

$$\pm \sqrt{0.2218}$$

$$\pm 0.471$$

$$= 0.461 \text{ cm}$$
$$= 0.181'' \quad = \# 7 \text{ B.W.G.}$$

ft per ω = 3140 ∴ 325.0 feet = 209 turns = 7600 A.T. per spool
cover = 0.195" = 37 turns per layer = 5½ layers = 1.2" dep.
energy 38" × 0.104 = 150 watts ÷ 1065 sq. cm = 7 sq. cm per watt.
wt. = 0.1036 × 307.8 = 31.9 lbs.

20 lbs of wire are to have a res. of 0.1036.
1 " " " " " 0.00518 " #5 nearest size

ft per ω = 2640 = 290 feet = 179 turns @ 35 amp = 6275 A.T.
0.11 ω × 28 = 3.08 ω in all @ 110 volts = 35.7 amperes.
the feet lbs per ω = 217.3 × 0.11 = 23.90 lbs. = 670 lbs on 28 spools

Magnetic induction through a large one milling electro-magnet of horse shoe shape.

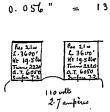
(99)

Diam. of core 13 cm = 133 sq. cms. cross sectional area.
5 turns of wire led to ballistic galvanometer with 12,200 ω added = 17500 ω in all reversals give 235 divs. = 117.5 divs for induction
1 G.B. 1¢ = 80 divs.
∴ $1.43 \times 10^4 \times 10^{-15}$ give 80 divs ∴ 1 div represents $1.43 \times 10^{-7}/0.80 \times 10^2$
$= 1.8 \times 10^{-9}$ units of quantity.
117.5 divs = 211.5×10^{-9} = 2.115×10^{-7} units.
∴ $2.115 \times 10^{-7} \times 1.75 \times 10^{13} = 3.70 \times 10^6$ lines ÷ $1.33 \times 10^2 = 2.8 \times 10^4$
÷ 5 = 5600 lines per sq. cm.
On laying the one in bulk over the pole on wood 0.225" thick the throw increased to 2140 divs; and on laying a strip of iron at about the same distance from the pole it increased to about 320 divs.
The spools of wire on these magnets have an internal diam of 5.25" an external diameter of 7.13" and are 7.25" interflange. The wire is 0.021" covered to 0.040" about 155 turns to the layer and about 28 layers and 18 lbs in all. so that the total number of turns on each spool is about 3,87,50
By trial it was found that the right excitation was obtained with about 18 amperes through 8 spools in multiple arc = 1625 amperes through each, so that the amperes-turns to be supplied are 2 × 3875 × 1.63 = 12,630 say 12,000. The radiating surface is 7.25 × 3.142 × 7.13 × 6.45 = 1065 sq. cms and the energy 1.63 × 1.63 × 55 = 146 Watts. 7.3 sq cms per Watt, so that even though the magnet might be reduced in diameter, the surface of the wire cannot be reduced.
To supply 150 Watts from 500 volts the current must be 2.73 amp. and the res: 20.15 ω.
The winding space will be 0.7854 (18.11" − 13.33") 18.142 = 2170 cc
Consequently the diameter of wire will be

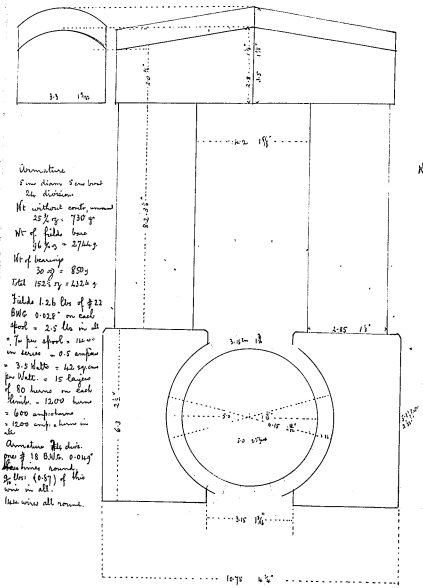
$$d = -0.01 \pm \sqrt{\left\{0.0004 + 0.00153\sqrt{\frac{2170}{20.15}}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153\sqrt{107.7}\right\}}$$
$$\pm \sqrt{\left\{0.0004 + 0.00153 \times 10.38\right\}}$$
$$\pm \sqrt{(0.0004 + 0.01588)}$$
$$\pm \sqrt{0.01628}$$
$$\pm 0.1276$$
$$+ 0.1176 \text{ cm} = 0.046''$$

17 B.&S = 0.0452

These diam: covered will be 0.060 and there will be 120 turns per layer. The mean diam: = 15.72 cms and mean circum: 49.4 cms. = 1.62 ft and the total number of feet will be about 4200 so that the number of layers being 16 = 1920 turns =
18 BWG = 0.049" @ 230 ft per ω = 4635 feet ÷ 1.62 = 2860
turns × 2.73 = 7810 ampere turns.
19 BWG = 0.042" @ 170 ft " " = 3595 feet. ÷ 1.62 = 2220
turns × 2.73 = 6060. Covered this wire will have a diam: of 0.056" = 130 turns per layer = 17½ layers = 0.98"



19.5 lbs of # 19 BWG. on each spool
4 magnet = 28 ~~amps~~ spools = 550 lbs.
Total current at 110 volts = 38 amperes.
Magnets of cast iron present dimensions.



Experiment to determine the effect of magnetisation on the gravitation pull.

Took a short cylinder of chaus stub steel 11.0 cms long and 0.1505" and 0.3823 cms diam. without any decided magnetisation and after letting it dry over H_2SO_4 carefully weighed it — 11.0135 grammes, the zero being then +1. Put 20 ampère through the large magnet and laid over its pole a strip of chamois leather, put the steel bar down on this strip for a few moments and then returned it to the scale pan. The balance was still 1.0+. Disturbing the rider 0.2.5 mgms threw the zero to 3.5 — so that 4.5 corresponds to 0.25 mgms and 1 to 0.055 mgms. It is probable therefore that if the weight had altered by 0.055 mgms and almost certain that if it had altered by 0.1 mgm the difference would have been detected. That is to say a certainly probable difference of 1 in 119135 = 0.0009(1/10)% or probably a difference of 1 in 200,200 = 0.0005 (1/2000 %)

The moment of inertia of the needle is approximately

$$11.014\left(\frac{12.1}{12}+\frac{0.1146}{4}\right) = 11.014\,(1.0083+0.0365)$$

$$= 11.014\,(1.0448) = 11.51 \text{ cm}^2 \text{ gms.}$$

The bar's period of vibration was found after the experiment to be approximately $\frac{305}{32} = 9.53$ sec. and with H = 0.189

$$M = \frac{\pi^2 \times 11.51}{9.53^2 \times 0.189} = \frac{9.87 \times 11.51}{90.83 \times 0.189} = \frac{1101.0}{17.17} = 64.1$$

$$I = \frac{M}{V} = \frac{64.1}{11 \times 0.7854 \times 0.3825 \times 0.3825} = \frac{64.1}{1.263} = 50.75$$

To determine the winding of a small motor to give enough power for a sewing machine, when working with a phonograph battery of 10 cells 7 volts @ 4.5 ampere. = 31.5 Watts.

Peripheral velocity 1000 ft per min = 500 cms per sec diam 6 cm = 18.84 = 26.5 revs per sec ∴ $\varphi n \times 26.5 = 7 \times 10^8$. Also the number of wire must be 6 × 24 = 144 ∴ $\varphi = 7 \times 10^8 / 144 \times 2.54 \times 10^3 = 1.91 \times 10^5$ and allowing 38% for leakage the total flux to provide for must be 2.86×10^5 say 3×10^5. The total air space is 1.15 and the area is (6.3 + 0.4) × 5 = 33 sq. cms. Hence the total air reluctance is $\frac{33}{1.15} = 28.7$. ∴ 1.25 T. at. = $28.7 \times 3 \times 10^5 = 8.61 \times 10^6$

The surface is $2.85 \times 3.14 \times 2 \times 8.2 = 147$ sq. cms on the field and allowing 25 sq. cms per watt = 6 Watts @ 6 volts = 1 ampere. With 0.5 amperes in the field coil, and a depth of 1.4 cms the winding space on each spool is $\frac{\pi}{2}(2.85+2.6) - 2.85 \times 8.2$

$$= 0.785\{(5.65)^2 - (2.85)^2\}\,8.2 = 0.785\,(31.92 - 8.12)\,8.2$$

$$= 0.785\,(23.8)\,8.2 = 153 \text{ sq. cms.}$$ and the rest of each spool must be 7.

$$d = 0.01 \pm \sqrt{\{0.00004 + 0.00153\sqrt{\tfrac{153}{7}}\}}$$

$$\pm \sqrt{\{0.00004 + 0.00153\sqrt{21.9}\}}$$

$$+ 0.00153 \times 4.68$$

$$+ 0.00716$$

$$+ \sqrt{0.00756}$$

$$+ 0.0869 \text{ cm} = 0.11$$

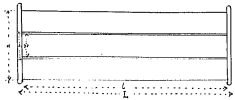
$$+ 0.0769 \text{ cm} = 0.0803$$

21 BWG = 0.032" − 0.044" cond = 70 turns per layer. Mean layer = 13.35 cms in circ = 0.438" ∴ 1 layer = 30.6 ft. and there are 700 feet = 23 layers

22 BWG = 0.028" + 0.040" cond = 80 turns per layer ∴ 35 ft × 832 ft = 15 layers = 0.66"

Armature wire # 18 BWG. 1440 turns of the drum × 10" = 1440" = 120 ft = 0.87 lbs

Inductance Measurements



No.	Description of Coil	Dimensions L	l	z	y	x	Diameter of conductor	Diameter of bent wire	Diameter of one wire	Resistance ± 0·1 mm	Capacity Resistance 25°C	Inductance Quadrants	Inductance Kilometer	Time Constant L/R in sec at temp.	Mutual Ind. Shunts		M Kilometer
1	Special coil	10·6	9·9	8·15	2·15	1·9	0·0195		No wire	166·502	0·120	0·0999	198·5	0·00120	0·072		
2	Plain single	29 layers of triple wound					0·1265	0·066	Cons.	16·402	0·121	0·0198	198·4	0·0012			
3	Plain double	26 layers of double wound								16·380	0·121	0·0198	198·2	0·0012			
4	w + b in ‖									8·243	0·243	0·0200	200·3	0·00243			
5	w + c ‖	Left hand half triple wound								5·509	0·366	0·0202	201·6	0·00367			
6	w + b series	Left = 1·243 = 2·243								32·487	0·2465	0·0801	800·8	0·002465			
7	. . . series									32·487	0·—	—	—				
8	a, b + c in series									49·2467	0·367	0·1809	1809	0·00367			
9	w + c in triple									16·402	0·2465	0·0802	401·8				
10										16·402	0·—	—	—				201·5
11	Step Plain	10·6	9·65	(3·7 + 5·95)	1·55	1·35	0·058	0·067	0·014	7·147	1·120	0·0801	800·5	0·01131			
12	Stepped with	10·6	9·9	6·15	2·15	1·9	0·0195	0·066	0·008	5·4324	3·35	0·1821	1821	0·03366			
13	Special	10·6	10·0	6·35	2·15	1·9	0·035	0·036	0·011	5·83	0·2037	0·0237	237·3	0·002144	0·100		
14		17 layers of 96 turns each								5·83	3·02	0·1761	1761	0·03073	0·800		
15	Barometric	10·6	9·3	5·70	2·35	1·8	0·035	0·036	0·010	5·577	4·13	0·2304	2304	0·04184	0·074	Length of coil	17·1
16	Special without wire	11·65	12·65	9·0	3·5	2·65	0·149	0·052	0·126	23·59	2·998	0·7072	7072	0·1387	18·49	Cons.	23
										5·152	1·115	0·0578	578	0·0713	0·082		
17	Special	0·15	4·8	6·0	2·3	1·90	0·035	0·038	0·010	5·9	3·70	0·2183	2183	0·0377	0·11	Cons.	17·1

See Book VII for data given in Phonograph Work.

* No change in the inductance of any one coil was noticed when that adjacent to it was short-circuited.

N.B. The reasoning on this page is faulty.

The most simplest case is as follows:—

A coil of resistance ρ and inductance λ is excited by a source E applied to its terminals. The source E being removed the coil is discharged without spark or loss of energy through a line of resistance r and inductance l. To find the conditions of discharge assuming no permittance in the line.

At any time t seconds after breaking contact at key

$$\lambda \frac{d^2q}{dt^2} + l\frac{d^2q}{dt^2} + (\rho+r)\frac{dq}{dt} = 0$$

$$\frac{d^2q}{dt^2}\left(\frac{\lambda+l}{\rho+r}\right) = -\frac{dq}{dt}$$

$$\therefore \frac{d^2q}{dt^2} = -\frac{1}{T}\frac{dq}{dt} \quad \text{where } T = \frac{\lambda+l}{\rho+r}$$

$$\frac{dq}{dt} = -\frac{q}{T} + m$$

$$\therefore q = \varepsilon^{\theta + \frac{t}{T}} + mT$$

when $t = 0$ $q = a$ the initial coil charge (1)

$t = \infty$ $q = 0$ (2)

$$\therefore a = \varepsilon^{\frac{\theta}{T}} + mT$$

$$= \varepsilon^{\frac{\theta}{T}} \quad \text{by (2)}$$

$$\therefore q = a\varepsilon^{-\frac{t}{T}}$$

$$c = \frac{dq}{dt} = -\frac{a}{T}\varepsilon^{-\frac{t}{T}}$$

$$\frac{de}{dt} = \frac{d^2q}{dt^2} = \frac{a}{T^2}\varepsilon^{-\frac{t}{T}}$$

The charge in the coil commencing at the value $a = C\theta = \frac{E\lambda}{\rho}$ declines logarithmically.

The current in the line and coil commencing at the value $-\frac{a}{T}$ $= -\frac{E\theta}{T} = -\frac{E\lambda(\rho+r)}{\rho T(\lambda+l)} = -\frac{E(\rho+r)\lambda}{\rho T(\lambda+l)}$ declines logarithmically.

The e.m.f. of discharge $\lambda\frac{d^2q}{dt^2}$ commences at $\frac{a\lambda}{T^2} = \frac{E\lambda^2}{\rho T^2}$

$$= \frac{E\lambda^2}{\rho^2 T^2} = \frac{E\theta^2}{T^2} = \frac{E\lambda^2(\rho+r)^2}{(\lambda+l)^2\rho^2}$$

The total energy of discharge $= -\frac{a^2(\lambda-l)}{T^3}\int_0^\infty \varepsilon^{-\frac{2t}{T}}dt = \frac{(\lambda-l)a^2}{2T^2}$

$$= \frac{E\lambda}{2}\frac{(\lambda-l)}{(\lambda+l)}\frac{(\rho+r)^2}{\rho^2} \quad \text{where } l = 0$$

Calculations for a multiplex Edison dynamo to be run direct from an engine at 220 revolutions per minute

Nov. 21st 89

The peripheral speed of the armature to be 125 feet per second. so that if d be the external diameter of the ring, $\frac{220\,\pi\,d}{60} = 125$ so $\pi\,d = 10.86$.

Phonoplex calculations.

Let λ be the inductance of a coil in a simple circuit containing the coil, an e.m.f. E and a total res. r. the source which is supposed to have no resistance is instantly withdrawn by being short circuited.

Then $+\lambda\frac{dc}{dt} + cr = 0$

$\psi\ \frac{\lambda}{r} = T$ $\quad +T\frac{dc}{dt} + c = 0$

$$\frac{dc}{dt} = -\frac{c}{T}$$

$$\frac{dc}{c} = -\frac{dt}{T}$$

$$\log_\varepsilon c = -\frac{t}{T} + k$$

When $t=0$ $c = C$ $\quad \log_\varepsilon C = k$

$$\therefore \log_\varepsilon \frac{c}{C} = -\frac{t}{T}$$

$$\frac{c}{C} = \varepsilon^{-\frac{t}{T}}$$

$$c = C\varepsilon^{-\frac{t}{T}}$$

$$\frac{dc}{dt} = -\frac{C}{T}\varepsilon^{-\frac{t}{T}}$$

counter emf. $\lambda\frac{dc}{dt} = -\frac{\lambda}{T}C\varepsilon^{-\frac{t}{T}}$

$$= -\frac{\lambda r}{\lambda T}\frac{E}{r}\varepsilon^{-\frac{t}{T}}$$

$$= -\frac{E}{r}\varepsilon^{-\frac{t}{T}}$$

So that in such a simple circuit the numerical value of the extra current e.m.f. commences with the permanent potential difference on the coil and falls logarithmically. consequently the current commences in like manner at the initial value $\frac{E}{r}$ and falls logarithmically.

$$c = \frac{dq}{dt} = C\varepsilon^{-\frac{t}{T}}$$

$$dq = C\varepsilon^{-\frac{t}{T}}dt$$

Total discharge $\left\{ \begin{aligned} Q &= C\int\varepsilon^{-\frac{t}{T}}dt \\ &= CT\varepsilon^{0} = CT \\ &= \frac{ET}{r} = \frac{E\lambda}{r^2} \end{aligned} \right.$

that is to say the total discharge is equal to the amount of electricity that flows in the permanent state through the circuit during the period of time T called the time constant.

At any moment the emf. of discharge is

$$\eta = \frac{\lambda}{T}C\varepsilon^{-\frac{t}{T}}$$

and the quantity dq discharged $dq = C\varepsilon^{-\frac{t}{T}}dt$

$$\therefore dE = \eta\,dq = \frac{\lambda}{T}C^2\varepsilon^{-\frac{2t}{T}}dt$$

Total energy of discharge. $\left\{ \begin{aligned} \therefore E &= \frac{\lambda}{T}C^2\int_0^\infty \varepsilon^{-\frac{2t}{T}}dt \\ &= \frac{\lambda C^2}{2} = EC\frac{T}{2} \end{aligned} \right.$

that is to say the total electromagnetic momentum of the coil is half the energy developed in the permanent state throughout the circuit during the interval called the time constant.

Calculation of size of copper wire for rail connections on car track.

a. rail has say 2 sq. in. of ~~cross~~ cross section = 2.55 m. c. mils.
the equivalent in copper being say $\frac{1}{5}$ R = 364,000 c. mils
a no 10 B&S wire 0.1324" has 18,000 c. mils.
= 20 wires

20 wires in all would be 10 wires (there and back) on each side. The fishplates being 1.5' long the wires would be 2' or cut in lengths of 4'. So that each joint would take 40' of #10 B&S. The track is 2750 feet long making 92 joints lengths in each rail = 184 lengths in all say 190 x 40 = 7600 feet of #10. @ 0.05244 = 413.5 lbs @ 20 cts = $82.

On the density of current on a large steel steam ship's hull supplied by 20 HP

For continuation see page 120

20 HP. = 15 kwt. and 5 volts = $\frac{15000}{5}$ = 3000 amperes.

A vessel 500 feet long and drawing 25 feet of water might for rough purposes be supposed to have the exact shape of an equilateral triangle in immersed section. The slant sides would be about 30 feet in breadth = 1.0 sq. feet per foot of length = 36 000 sq. feet = 1 ampere per 12 sq. feet. = 1 ampere per 11,200 sq. (roughly) 1 ampere per sq. metre.

2 Mr. Noyes took two strips of steel 0.012" thick (0.03 cm) 3" (7.6 cm) wide and 8" (20 cm) long. Shellacked one side of these and immersed them each upright in a jar of salt water :— a fantastic photographic cell with tap water containing NaCl in solution to imitate sea water. sp. g. 1.03 @ 16°C.

One jar with the strip immersed was set aside the other had the strip connected with the Zn pole of two small Bunsen cells, a steel rod forming the opposite electrode. A res. of about 200 ω maintained the current at 0.015 amp. which is approximately equivalent to 1 ampere per sq. foot-metre. Current started at 15 Volts. Bubbles of hydrogen visible on surface of steel.

On the effectiveness of Phonoplex induction coils.

Before discharge an e.m.f. E is maintained at the coil terminals producing a steady flow $\frac{E}{R} = C$. On instantaneously interrupting the battery cct., supposing that possible, this flow C will fall to a value c_1 common to the entire line cct. The time required to effect this is the small interval δt needed by the time of force to withdraw into the coil axis and vanish. All causes that increase the magnetic lag or set up eddy currents in the coil or core tend to prolong δt. At the close of the period the e.m.f. in the coil had risen to $\lambda(C - c_1)$ and the applied e.m.f. from the line assuming $\frac{dc}{dt}$ negligible retardation is $L c_1$. The effective e.m.f. at that moment would thus be $\frac{\lambda C - c_1(\lambda + L)}{\delta t}$ and this must = $c_1 R$ where R is the total res: in cct.

$$\therefore c_1 = \frac{\lambda C}{\lambda + L + R\delta t}$$

To a first approximation therefore, provided that the quality and form of coil ~~core~~ remains R constant, the value of a coil depends upon λC or $E\frac{\lambda}{R}$ or ET, or $\frac{E}{\rho + b}\lambda = \frac{E\,l}{\rho + b}$ where b is the res: of the battery. In other words upon the e.m.f. and time constant of the changing cct.

On the number of turns and size of wire necessary for the series winding in the car transformer field magnets.

The diameter of the core 7⅛" = 7.375", and over lapes say 7.125". a circumference of 23.14", and over the winding the diam: is 10.25" say in this instance 10.5" a circumference of 32.0", under lape say 32.6 the mean circumference being ½ (32.6 + 23.14) = 28". The normal exciting power is about 8000 ampere-turns, and some 1000 ampere turns might be taken as exciting power off the high volt circuit. The current being 12 amperes at full load = 8⅔ turns say 100, or 50 on each limb. 100 turns = 2800" = 233 ft. the energy lost at full load should not exceed 50 Watts = $\frac{50}{100}$ = = 0.35 w = 0.35 w per foot = 0.0015 w per foot = # 14 B.W.G. wire 0.088" = 0.095" circut. = # $\frac{233}{12}$ wire high + 12# deep = 1.114" deep and 0.38" high perhaps with lape 1.25" deep and 0.5" high.

Test of the armature of the No. 4 car transformer on completion Dec: 7th.

Diameter of armature over wire — over bare wire
Resistance of coarse wire set ϕ brush to brush about 0.03 ω
- - fine - - - - - - 5.3 ω
Insulation resistance between sets and to base o.k.
Res: of each section of fine wire 0.195 ω (shunted by all other sections).
One section found to have irregular res: probably imperfect soldering.

Test of the No. 4 transformer with above armature on completion. December 8th

First started machine with 100 volts on primary sec: per and 11 amperes separately supplied to fields. Compound coil out of circuit. Speed 180 revs: per min:
At 1 o'clock Ran machine from municipal dynamo with 21 volts on secondary (o/pins) 21×50 # 1×5 = 1055 volts on primary 0.6 amperes and 12.5 amperes in field separately excited. Compound coil out of cct. Speed 1760 revs: per min. No sparking. Pressure on field 24 volts. Ran for about 15 min: No sparking, some but little vibration and no evidence of undue heating.
20.50 Succeeded after several trials in making transform: start and self excite from rest. P.D. on secondary terminals (o/pins) 21 volts on primary (calculated) 1055 current 0.95 amperes = 1002 Watts. (400 utilised in fields) speed 1900 revs: per min. Running well.
22.20 Stopped running. Bearings blood warm. Put thermometer on armature under wires. Highest temp: 110°F = 42°C. Temp: of air about 70°F = 21°C.

Recalibration of Alternating Current Ammeter for Messrs Bergmann & Co. Dec. 8th.

Speed of Dynamo 2045 revs. per min: driven by belt from flywheel of #2 engine. = $\frac{2045}{60} \times 8$ = 286 alternations = 143 periods per second. The cardew voltmeter was calibrated from the continuous current and then used with the alternating current using various measured resistances of bare platinoid wire stretched up and down the laboratory. The readings were from 0 up to 1.6 amperes and did not differ greatly from those obtained in the previous calibration as recorded in the last Record-Book. The resistance of the instrument was observed to be 1.94 ω @ 20°C and its inductance to vary between 0.003 quadrant with the pointer at zero, and 0.807 quadrants at 1.6 amperes. (2.01 ω w/o 15'.4307)

Test of a specimen of Insulating material for Messrs Bergmann & Co.

Substance resembling hard rubber in appearance, but perhaps moulded with aid of glue from rubber crushed. Soft. Would not take polish. Would not take thread or turn in the lathe. Soluble in water. KHO 10%. NH_4HO, vinegar, alcohol vs. Blisters and cracks under severe heat. Does not nourish flame. Sp. g: 1.36. Swells when soaked in water. Very soft and easily filed. Will perhaps serve for some mechanical purposes where strength is not needed.

Installation of Storage Battery for Pennsylvania R.R. Co. at Philadelphia

105 cells @ 0.75 volt = 79 volts + 2.6 ω @ 0.025 ω each

70 cells @ 0.75 volt.
= 52.5 volts + 1.75 ω
@ 0.025 ω each.
300 amp. hrs

Whole battery 175 volts @ 0.75 volt
= 130 volts @ 0.025 ω
= 4.4 ω

Delivering 7 × 0.033 = 0.233 amp.
= 5.6 amp hrs daily
= 27 days work.
@ 150 amp hrs.

Line	Volts	Wd. ω	C.					
P.R.R. #13	52.5	17500	0.033	37	7800 ω	110	N.Y. #12	240 ω 7830 ω
P.R.R. #15	52.5	1760	0.033		4730 ω	320	P.R.R. #2	160 4775
Ky. #7	162.5	6030	0.027	37	5590 ω	110	P.R.R. #1	200 6000
P.R.R. #18	52.5	1750	0.030	180 ω 37	4220	320	P.S.U. #1	210 6270
P.S.U. #2	132.5	4650	0.030	37	10500	320	N.Y. #13	160 4770
P.R.R. #14	72.5	2210	0.033	1900 ω	4270	320	P.R.R. #9	210 6300
P.R.R. #24	52.5	1590	0.033	37	4090	320	P.R.R. #21	162 4840

35 cells @ 0.75 volt
= 26 volts + 0.75 ω
@ 0.025 ω.

delivering 0.2 amp hr
= 4.8 amp hrs daily
= 6½ days at work
for 300 amp hrs

	P.R.R. #23	26 ω	950 ω 0.025
110	Mny. #2.	136	3225 0.038
	P.R.R. #22	26	975 0.025
	H.E. Line	26	980 0.025
	P.R.R. #12	26	1020 0.025
	P.R.R. #19	26	1020 0.025
	P.R.R. #4	26	1030 0.025
	P.R.R. #20	26	990 0.025

Total equipment 105 cells of 150 amp hrs.
105 - - 300 - -
7200 ω of resistances.

Note

Traction Calculations.

Let m be the mass of the car complete with material and personnel.
n . . . . . passengers.
μ . . coefficient of friction.
v . . velocity of the car (assumed uniform).
p . . pull delivered at the axles
θ . . gradient.

Then the pressure of the ~~f~~ loaded car on the track is in lbs $g(m+n)$, and the pull exerted is expressed by the equation

$$p = \mu g(m+n) + g(m+n)\sin\theta$$
$$= g(m+n)(\mu + \sin\theta)$$

so that the rate of doing work is

$$w = pv = gv(m+n)(\mu + \sin\theta) \text{ ergs per second.}$$

and expressed in watts this becomes

$$W = gv(m+n)(\mu + \sin\theta)\,10^{-7} \text{ watts}$$

$g = 981$
μ varies between 0.0056 and 0.0089 for locomotive rails
0.0125 . 0.025 . streets .

m = 5500 lbs say = 3,850,000 = 3.85×10^6
n = 30 passengers @ 1155 lbs say . 4350 lbs = 1.97×10^6 } $m+n = 5.8 \times 10^6$
7 miles per hour = 313 cms per sec. = v
for $\theta = 0$ $W = 0.981 \times 10^3 \times 3.13 \times 10^2 \times 5.8 \times 10^6 \times 2.0 \times 10^{-2} \times 10^{-7}$
$= 3.7642 \times 10^3$
$= 3.76$ kwts loaded.

The highest gradient on the routes is 0.04 in which case the loaded car at 7 miles per hour will take at its axles 10.7 kwts.

Car running Empty					Car loaded with 30 passengers				
Miles per hr.	Level kwts.	1% kwts	2% kwts	4% kwts	Miles per hr.	Level kwts	1% grade kwts	2% kwts	4% kwts
1	0.34	0.51	0.68	1.02	1	0.51	0.77	1.02	1.54
3	1.02	1.53	2.04	3.06	3	1.53	2.30	3.06	4.60
5	1.69	2.54	3.38	5.08	5	2.55	3.82	5.10	7.64
7	2.37	3.56	4.74	7.12	7	3.57	5.36	7.14	10.72
10	3.38	5.07	6.76	10.14	10	5.09	7.64	10.18	15.28

For the direct pull of starting,

$$p = g(m+n)(\mu + \sin\theta)$$

in cgs $= 981\,(5.8)\,10^6\,(2.0)\,10^{-2}$
$= 11.6 \times 0.981 \times 10^7 = 11.38 \times 10^7$
$= 1138$ megadynes
$= 11.6 \times 10^{10}$ } on level
$= 116$ kgms.
for 10% grade $= 981\,(5.8)\,10^6\,(12.0)\,10^{-2}$
$= 682$ megadynes
$= 69.6 \times 10^{10}$ } on 10% grade
$= 696$ kgms

$p = (m+n)(\mu + \sin\theta)$
$= 12{,}850\,(0.02)$
$= 257$ lbs on level
$= 12{,}850\,(0.07)$
$= 899.50$ lbs on 5% grade
$= 900$ lbs fair max.

Total rainfall for month of

January = 5.04"
February = 2.21"
March = 2.91"
April = 6.36"
May = 3.00"
June = 1.86"
July = 15.25"
August = 4.31"
September = 11.54"
October = 2.56"
November = 13.25"
December = 2.99"
Total rainfall for the year 1889 = 71.28 inches

Meteorologicae report to Bureau department. W. S. Rosenmuller.

Highest Winter Temp. 56° Jan 17th 1889, 63° Jan 12th & 21st 1890
Lowest " 13° Feb 23rd 1889, 20° Jan. 22nd 1890
Mean annual Temp. 56°
Average annual rainfall, 71.28 inches for 1889.

Meteorological record.

Continued from p. 62

Date	Time	Barometer readings Inches	Cm	Temp.	Corrected 0°C	Thermometer Max	Min	Dry	Wet	Rainfall 24 hours	Wind	Remarks.
1889												
Dec. 14		30.032	76.29	66°	29.930	41°	26°	29°	—	Snow	NE	Overcast
15		29.912	75.98	54°	29.846	42°	24°	40°	34°	—	NE	Fine
16	Noon	29.948	76.07	71°	29.881	48°	21°	46°	42°	—	NE	Fine
17		30.028	76.27	70°	29.914	49°	38°	45°	45°		NE	Overcast
18		29.968	76.11	68°	29.260	54°	31°	53°	51°	0.48	NE	Overcast
19		29.750	75.56	70°	29.624	56°	36°	50°	48°	0.25	NE	Fine
20		29.710	75.46	70°	29.586	53°	36°	48°	47°	0.01	SW	Overcast, Rain
21		30.120	76.50	74°	29.982	50°	24°	46°	43°	—	W	Fine
22		29.934	76.05	74°	29.862	48°	34°	39°	36°	—	W	Fine
23	Noon	29.854	75.79	72°	29.796					0.89		Rainy, overcast
24		29.752	75.57	70°	29.688					0.24	SW	Rain
25		29.716	75.47	68°	29.608						SW	Fine
26		29.762	75.59	73°	29.639	65°	42°	42°	41°	0.74	NE	Overcast, thunder
27		29.710	75.48	70°	29.580	53°	38°	36	34°		NE	Fine, storm
28	12 —	29.800	75.81	76°	29.718	54°	30°	43°	43°	—	W	Fine
29	11.30	29.962	76.11	62°	29.092	45°	30°	38°	34°	—	W	Overcast
30		30.136	76.55	70°	30.032	51°	30°	40°	39°	—	N	Overcast, showy
31		30.024	76.26	74°	29.898	50°	28°	41°	39°	—	NW	Fair
1890												
Jan. 1						60°	31°	39°	39°		SE	Overcast
2		30.104	76.47	73°	30.061	64°	37°	49°	48°	0.03	W	Overcast
3		30.430	77.30	76°	30.298	62°	34°	44	40	—	NW	Fine
4		30.420	77.27	72°	30.295	46°	26°	30°	30°	—	N	Fine
5		29.750	75.56	60°	29.666	55°	45°	38°	38°	—	W	Fine
6	Noon	29.892	75.93	67°	29.792	55°	32°	45°	44°	—	SW	Overcast.
7		29.900	75.92	69°	29.962	59°	26°	46°	47°	—	W	Fine
8		29.602	75.20	79°	29.461	59°	49°	48°	47°	—	W	Fine
9		29.574	75.13	78°	29.464	46°	36°	30°	29°	—	NW	Fine
10		29.572	75.17	78°	29.638	48°	32°	36°	34°	—	W	Fine
11		29.364	74.62	75°	29.835	58°	36°	53	52°	—	NW	Overcast
12		29.938	76.05	68°	29.850	60°	35°	48°	40°	—	W	Overcast
13	Noon	29.530	75.03	79°	29.387	65°	37°	45°	44°	—	W	Overcast with
14		30.026	76.24	76°	29.244	46°	36°	42°	38°	—	NW	Fine
15		30.010	76.24	76°	29.900	60°	35°	49°	40°	1.50	NW	Fine
16		29.612	75.25	74°	29.538	60°	35°	44°	41°	0.37	SW	Overcast showy
17		29.570	75.04	70°	29.538	54°	35°	44°				
18		30.246	76.77	70°	30.122	43°	27°	34°	33°	—	N	Fine
19		30.200	76.70	60°	30.092	38°	24°	36°	—	—	W	Fine
20		29.600	75.20	70°	29.472	48°	29°	40°	—	0.16	E	Fine
21	Noon	29.950	75.89	73°	29.737	69°	31°	52°	48°	[illegible]	SW	Fine, overcast
22		30.180	76.62	62°	30.000	60°	35°	50°	—	[illegible]	W	Fine
23		30.228	76.78	66°	30.150	55°	25°	50°	—	[illegible]	W	Fine
24		29.830	76.00	69°	29.693	55°	29°	35°	—	—	NW	Overcast
25		29.744	75.58	72°	29.494	59°	29°	38°	0.03	0.02	W	Overcast
26		29.990	76.13	73°	29.867	43°	30°	36°	—	0.16	W	Overcast, fair
27		29.264	74.37	70°	30.150	47°	36°	36°	33°	0.00	NW	Fine
28		30.124	76.51	72°	30.007	57°	33°	44°	41°	.92	SW	Fine
29		30.022	76.27	76°	29.916	57°	37°	45°	—	—	NE	Fine
30		30.122	76.53	76°	29.990	46°	35°	39°	—	—	S.E.	Overcast Fair
31												
Feb. 1		30.292	76.92	77°	30.157	43°	39°	40°	—	—	W.	Overcast. Fair
2		30.224	76.72	63°	30.091	46°	28°	37°	—	.11	S. W.	Rainy
3		29.890	75.93	75°	29.761	47°	32°	41°	—	—	W.	Overcast
4		30.010	76.24	78	29.832	50°	39°	42°	—	.42	W.	Overcast Rainy
5												
6												
7		30.351	77.20	58°	30.233	60°	17°	26°	—	—		Overcast Fair
8		29.453	74.80	78°	29.316	59°	26°	51°	—	.15	W.	Overcast Rainy.
9		30.335	77.06	68°	30.294	52°	21°	27°	—	.44	S. W.	Fair
10											W.	Overcast Fair
11		30.340	77.09	70°	30.221	32°	25°	25°	—	—	S. W.	Fair
12		29.940	75.98	75°	29.781	49°	38°	44°	—	—	S. W.	Fair
13		30.087	76.36	76°	29.917	47°	22°	40°	—	—	W. C.	Overcast Fair
14		29.655	75.41	76°	29.531	46°	32°	45°	—	—		
15		29.776	75.69	75°	29.581	51°	46°	45°	—	.68	W.	Overcast Rainy
16		30.300	76.95	65°	30.203	46°	26°	31°	—	—	S. W.	Fair
17		29.916	76.00	76°	29.816	45°	31°	44°	—	—	S.	Fair
18		29.553	75.14	78°	29.415	60°	39°	55°	—	—	S. W.	Fair
19		29.728	75.02	76°	29.676	68°	32°	57°	—	—	W	Fair
20		29.408	74.71	75°	29.279	41°	31°	40°	—	.73	W	Rainy, Rain, Snow
21		29.854	75.88	66°	29.732	48°	18°	25°	—	—	W	Fair
22		29.876	75.88	53		34	20	32				
23		29.850	75.83	70		30	20	35				
24		29.840	75.80	72	29.720	44°	22°	40°	—	.11	S. E.	Cloudy Rainy
25		29.804	75.71	74°	29.678	46°	40°	43°	—	.10	N. E.	Cloudy
26		29.703	75.45	79°	29.562	60°	43°	63°	—	.05	N. E.	Fair
27		30.000	76.20	77°	29.865	63°	39°	47°	—	—	N E	Fair
28		29.757	75.62	76°	29.625	54°	37°	43°	—	.44	N. E	Rainy.

Measurement of the effect of tinning a copper wire upon its resistance, for The Edison Machine Works.

Two lengths of wire # 19 B&S soft copper were received from Schenectady; each was about 600 cms long but one was tinned while the other was in its natural condition. These wires were carefully uncoiled to avoid twists or stresses and were laid parallel along the floor. One end of each was fastened down, and the opposite free ends were kept fairly tight by a weight of some 2900 grammes applied by a wire running over two pulleys. The two tested wires were thus parallel, almost horizontal and about 3 cms apart. A current from 2 nitro-chromic cells was sent through them in series and brass knife edges beneath them placed adjustable portions of their lengths in connection with the differential galvanometer. By means of a micrometer screw gauge the diameters of these wires were observed as follow:—

No. of obs.	Diam. of Tinned wire in inches	Δt $\times 10^{-4}$	v^2 $\times 10^{-8}$	$\frac{4\Delta t \sqrt{v^2}}{\sqrt{n(n-1)}}$	Probable Diam. in cms	No. of obs.	Diam. of untinned wire in inches	v	v^2	$\frac{0.67\Delta t \sqrt{v^2}}{\sqrt{n(n-1)}}$	Probable diam. in cms.
1	0.0415	9	81	5.51×10^{-4}		1	0.0422	1	1	3.75×10^{-5}	
2	25	1	1	Result		2	22	1	1	Result	
3	26	2	4	0.0412.1109 ± 0.000055	0.10775 ± 0.00014	3	22	1	1	0.0412.104 ± 0.000038	0.10697 ± 0.00010
4	22	2	4			4	23	2	4		
5	20	4	16			5	18	3	9		
6	25	1	1			6	20	1	1		
7	23	1	1			7	21	0			
8	34	10	100			8	22	1	1		
9	26	2	4			9	22	1	1		
10	23	1	1			10	22	1	1		
11	26	2	4			11	17	4	16		
12	23	1	1			12	22	1	1		
13	22	2	4			13	16	5	25		
14	22	2	4			14	23	2	4		
15	25	1	1			15	23	2	4		
16	22	2	4			16	16	5	25		
17	32	8	64			17	19	2	4		
18	22	2	4			18	21	0			
19	24	0				19	23	2	4		
20	25	1	1			20	22	1	1		
21	21	3	9			21	28	7	49		
22	25	1	1			22	21	0			
23	26	2	4			23	19	2	4		
	594		Σv^2 314				484		Σv^2 157		
Mean	0.0412 499		$\sqrt{\ } = 177 \times 10^{-4}$ $\frac{177}{5.74 \times 10^{-4}}$				0.0412.104		$\sqrt{\ } = 1.25 \times 10^{-4}$		

The difference in diameter is thus 0.00079 cms or a mean tinning thickness of 0.00039 cm. Ratio of diameter 1.0075. If the layer of tin had the conductivity of copper the conductance of these two wires would be in the ratio of 1.015 nearly, or would differ by about 1½ %, owing however to the inferior conductivity of tin, the difference is decidedly less.

No.	Length untinned	Length tinned	Difference	Ratio		No.	Length untinned	Length tinned	Difference	Ratio	Mean Ratio
1	595.4	600	4.6	1.0078		6	352.7	353.7	1.0	1.0030	
2	532.4	535	2.6	1.0049		7	294.5	295.5	1.0	1.0035	
3	494.5	498	3.5	1.0071		8	237.7	238.3	0.6	1.0027	
4	453.1	456.5	3.4	1.0077		9	182.0	182.5	0.5	1.0028	
5	400.3	403.7	3.4	1.0088		10	593.4	597	3.6	1.0060	1.0054

log 0·1069742 0·0028
0·0534425 5·7282320
5·4561640
π 0·4971509
3·9536129 0·008987

Table of tinned copper wires.

Diam. of wire inches	Thickness of tinning in inches or $\frac{d}{2}$					
	0·00005" %	0·00010" %	0·00015" %	0·00020" %	0·00025" %	0·00030" %
0·010	1·5	3·0	4·5	6·0	7·5	9·0
0·020	0·75	1·5	2·3	3·0	3·8	4·5
0·030	0·5	1·0	1·5	2·0	2·5	3·0
0·040	0·4	0·8	1·1	1·5	1·9	2·25
0·050	0·3	0·6	0·9	1·2	1·5	1·8
0·060	0·25	0·5	0·75	1·0	1·25	1·5
0·070	0·2	0·4	0·6	0·9	1·1	1·3
0·080	0·2	0·4	0·6	0·8	0·9	1·1
0·090	0·2	0·3	0·5	0·7	0·8	0·9
0·100	0·15	0·3	0·45	0·6	0·75	0·8
0·110	0·1	0·3	0·4	0·5	0·7	0·85
0·120	0·1	0·15	0·4	0·5	0·6	0·75
0·130	0·1	0·2	0·3	0·4	0·5	0·7
0·140	0·1	0·2	0·3	0·4	0·5	0·65
0·150	0·1	0·2	0·3	0·4	0·5	0·6
0·160	0·1	0·2	0·3	0·4	0·5	0·55
0·170	0·1	0·2	0·3	0·4	0·4	0·5
0·180		0·2	0·25	0·3	0·4	0·5
0·190		0·2	0·25	0·3	0·4	0·5
0·200		0·15	0·2	0·3	0·4	0·45
0·210		0·1	0·2	0·3	0·35	0·4
0·220		0·1	0·2	0·3	0·35	0·4
0·230		0·1	0·2	0·3	0·35	0·4
0·240		0·1	0·2	0·25	0·30	0·4
0·250		0·1	0·2	0·25	0·30	0·35

Working formula for centimetres

$$x = \frac{100\,t\,\{d(n-2) + t(n-1)\}}{nr^2 + 2rt}$$

$$= 100\frac{t}{r}\left\{\frac{6d + 7t}{8r + 2t}\right\}$$

$$= 100\frac{t}{d}\left(\frac{6d + 7t}{2d + t}\right)$$

$$= 50\frac{t}{d^2}\,(6d + 7t)$$

$$= 300\frac{t}{d} \text{ for cms.}$$

$$= 750\frac{t}{d} \text{ for inches}$$

The table gives the effect % of any given thickness of tinning on the conductivity of the wire.

The resistance of 523·2 cms. of the untinned copper wire @ 18°C was found to be equal to the 0·1 Ω std. coil @ 19·2°C. This resistance is correct @ 14°C. 19·2 − 14 = 5·2 × 0·03 = ·156 Ω actual res. would therefore be 0·10016 Ω.
The res. per cm. of wire would be $1{\cdot}91444 \times 10^{-4}$
area being 0·008987 sq. cm. ; its resistivity = $1{\cdot}721 \times 10^{-6}$ Ω @ 18°C.
98 × 0·388 = 6·9824 1·721 ÷ 10·698 = 160 g abs. units
a conductivity of = 100·7 %.

The tinned wire would have a conductivity of

$$\frac{100{\cdot}7 \times 1{\cdot}00544}{1{\cdot}015} = 99{\cdot}7\ \%$$

so that the effect of tinning was apparently to reduce the conductivity one per cent.

Mathematical Theory of the effect.

To find the modification of conductivity in a tinned wire assuming that the wire is a right cylinder and that the tin is deposited cylindrically on its surface while the two metals retain their independent conductivities.

Let r be the radius of the wire (cms)
R " " " " tinned wire
t " " thickness " tinning = $\frac{d}{2}$.

The conductance of the wire alone is $\frac{\pi r^2}{\rho_c}$ per unit length where ρ_c is the resistivity of the copper

The conductance of the layer of tin alone is $\frac{\pi(R^2 - r^2)}{\rho_t}$ per unit length where ρ_t is the resistivity of the tin.

The total conductance is thus $\frac{\pi r^2}{\rho_c} + \frac{\pi(R^2 - r^2)}{\rho_t}$ per unit length

Let $\rho_t = n\rho_c$ then $C = \frac{\pi r^2}{\rho} + \frac{\pi(2r + t)t}{n\rho}$ . . .

$$C = \frac{\pi(nr^2 + 2rt + t^2)}{n\rho} \quad . \quad .$$

The total resistance is thus $= \frac{n\rho}{\pi(nr^2 + 2rt + t^2)}$ . .

The apparent total resistivity is therefore $= \frac{n\rho\{\pi(r+t)^2\}}{\pi(nr^2 + 2rt + t^2)}$ . . .

$$\rho_{app} = \frac{n\rho R^2}{nr^2 + 2rt + t^2}$$

Let x be the apparent percentage loss of conductivity. Then

$$\frac{\rho_{app}}{\rho} = \frac{100 + x}{100} = \frac{nR^2}{nr^2 + 2rt + t^2}$$

$$\therefore x = \frac{100(nr^2 + 2rt + t^2 - nR^2)}{nr^2 + 2rt + t^2}$$

$$= -\frac{100(nr^2 + 2rt + t^2 - nr^2 - 2nrt - nt^2)}{nr^2 + 2rt + t^2}$$

$$= -\frac{100\{2rt(2-n) + t^2(1-n)\}}{nr^2 + 2rt + t^2}$$

$$= \frac{100\,t\{2r(n-2) + t(n-1)\}}{nr^2 + 2rt + t^2}$$

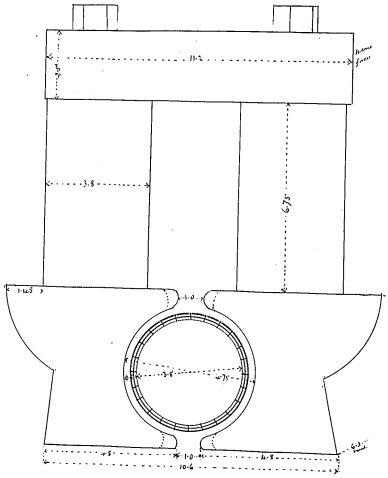
The tabular value of n for tin and copper is 8, so that for the above experimental case having r = 0·0535 and t = 0·00039

$$x = \frac{100 \times 0{\cdot}00039\{0{\cdot}107 \times 6 + 0{\cdot}00039 \times 7\}}{8 \times 0{\cdot}0535 \times 0{\cdot}0535 + 0{\cdot}2 \times 0{\cdot}00039}$$

$$= \frac{0{\cdot}039(0{\cdot}642 + 0{\cdot}0028)}{0{\cdot}0252 + 0{\cdot}0007}$$

$$= \frac{0{\cdot}039 \times 0{\cdot}6448}{0{\cdot}0253}$$

$$= 0{\cdot}99\ \%$$



Weight of field unwound 137 g. 3,880 g.
Diam. of limb $1\frac{1}{2}$" = 3.8
" " armature 1.5" = 3.8
Length " = 2.5 = 6.3

Flux necessary with 1 wire 38 turns round for 500 cms per sec. = 2.16×10^8 = 7250 AT.
" obtained with 10 Watts per sq.cm. 2900.
Reluctance of magnetic cct. 0.032.

Armature
24 divs: 1 wire 38 (but probably) 36 turns round — Armature diam. when wound
2 layers of 114 — 4 layers of 114 = 4.55
Bifilar wire all round 2688 turns. all round
5700
Circumference of armature 38
Size of wire # 32 B.W.G. = 0.009 = .81 c.mil
162 c.mils will allow 0.3 amperes @ 500 c.mils per amp.
= 330 watts = $\frac{1}{13}$ HP.
Res. of armt. 15.8 $\frac{13}{320}$
Fields. wound with # 31 B.W.G. 0.010" silk cond. 23½ oz in all. 11¾ oz each limb
25 layers of 190 turns. for each limb.
Res. of field 1 250 ω each limb = 500 ω total. (cold) current 0.21 amp
Total current 0.5 amp. at full load.

Designed Small Motor of Edison Type

Calculations for its winding.

The diameter of the armature being 3.8 its circumference = 11.94. Out of this there will be 24 teeth each 0.005" = 0.0125 = 0.3. leaving 11.6 or 0.48 to each division. The wire employed on the armature is 0.009" measured say 0.014" covered. $\frac{0.034}{.014}$ = 114 on the first layer, so that 1 wire 38 turns round will give 4 layers. = 0.136 cm + 4 thickness of paper each 0.007 = 0.028" = 0.07 cm = 0.206 cm. thickness of winding = 4.2 cm diameter of armature.

Assuming a peripheral velocity of 1000 ft per min = 500 cms per sec. we have $56 \times 24 \times 37.9 \times \phi = 1.10 \times 10^{10}$ or $\phi = 2.16 \times 10^8$

$5.09 \phi = 1.10 \times 10^9$

The reluctance is $1.0 \times \frac{1}{5.0 \times 6.3}$ = 0.0318 and allowing 20% for leakage or 0.72×10^8 gives the required flux 2.88×10^8

$31.5 \times 1.26\ n = 2.88 \times 10^8 \therefore n = 7.25 \times 10^2 = 7250.$

The diameter of the field after winding will be about 5.5 a circumference of 17.3 and the total length = 13.5 so that the area = 233 sq. cms. Allowing 20 to the watt = 11.7 Watts. @ 110 volts = 0.1 amperes (hot) = 1100 ω (hot) 30°C = 1060 ω @ 20°C. (520 ω each)

Taking the internal diam: as 4 cms and the external as 5.5 the coiling space on each limb is $6 \times 0.785 \times (30.25 - 16) = 4.7 \times 14.25$ = 67 c.c.

$$d = -0.004 + \sqrt{\{(4.0 \times 10^{-3})^2 + 1.53 \times 10^{-3} \sqrt{\tfrac{67}{500}}\}}$$

$$+ 0.00153 \sqrt{0.0268}$$

$$+ 0.00153 \times 0.3556$$

$$0.00016 + 0.00054$$

$$\sqrt{0.000570}$$

$$\sqrt{5.7 \times 10^{-2}}$$

$$= 2.39 \times 10^{-1}$$

$$= 0.024 - 0.004$$

$$= 0.020 \text{ cms.} = 0.008".$$

The mean diam = 4.75 cms = 1.9" and the mean circumference 5.97" say 0.5 feet. There will be about $\frac{2500}{11}$ = 220 turns to the layer = 110 feet and the depth of winding is $\frac{1.5}{2}$ = 0.75 = 0.3" = $\frac{300}{13}$ = 27 layers = 2970 feet × 0.161 ω = 478 ω.

The number of turns will be about 6000 on each limb = 12,000 in all + the number of AT. 1200

Allowing 10 sq. cms per Watt = 23.2 Watts @ 110 volts = 0.21 amperes = 520 ω (hot) = 500 ω say coil on 250 ω on each limb

$$d = -0.004 + \sqrt{\{0.000016 + 0.00153 \sqrt{\tfrac{67}{250}}\}}$$

$$\sqrt{0.268}$$

$$0.52$$

$$0.000796$$

$$\sqrt{0.000812}$$

$$\sqrt{8.12 \times 10^{-4}}$$

$$0.0285 - 0.004$$

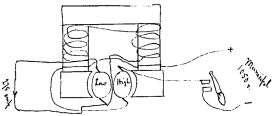
$$0.02485 \div 2.54 = 0.0096" \text{ say } 0.010" = 0.013" \text{ cmd.}$$

$\frac{2500}{13}$ = 190 turns per layer = 59.5 feet. + $\frac{300}{13}$ 23 layers = 2070 feet

Res. per layer = 190 turns in all × 0.21 = 1800 AT in all.
= 210 ω = 4370 turns per limb

Wgt. per ω of this wire # 31 B.W.G. = 0.00293 + 500 ω = 1.465 lbs = 23½ oz = 11¾ each limb

1 turn of the turns = 20 cms say 8" = 9.6" = 0.8' =



Preliminary Measurements of Car Transformer Work.

December 18th Transformer armature #2 ready. Res: of fine wire circuit between brushes 50 @ 20°C.

1st with field excited separately by 100 volts and lamp-bank 20. volts on field terminals

113.5 volts on for: 2·1 volts on secondary 193 revs: per min.

17 o'clock. Machine self exciting and loaded with 275 amperes obtained by employing overhead wires in multiple.

1000 (abt) volts on for 5·5 amperes. 5500 watts Efficiency 80%

16 " " per terminal 275 amperes. 4400 "

18 o'clock Stopped running. Highest temp. indicated by thermometer above armature under waste 127·F.

Description of shock accidentally received in preparing for above test.

The field magnets were separately excited but the series winding were in cct: with the municipal machine, high volt armature. Had stopped the transformer by opening the switch, but had not cut off the pressure from the wires leading from the dynamo. One of these wires connected with a transformer brush had by the movement of the rocker arm been brought in contact at a bare spot with the bed plate so that one terminal of the municipal dynamo was in communication with the framework of the transformer. Was examining a connection between lead, series coil for tightness and held it in the right hand resting on the 3rd phalanx of the middle finger. It was a brass connector. Had rubber galoshes on and did not feel any pressure on this connector. While still holding it must have accidentally touched the framework of the transformer with a knuckle of the left hand. This brought the pressure of 1050 volts upon the body through the two hands. Have no precise knowledge of the manner in which this contact was made nor of the duration of the same, but since the burn on the left hand was just at the outer knuckle of the middle finger between the second and third phalanges, I suppose that the contact was momentary only. The sensation was indescribable. It was a violent rending pain chiefly felt through the whole length of the arm but also ~~slightly~~ in the trunk. I imagined that the current was steadily flowing through me and have distinct recollection of making a voluntary effort to clear myself of the wire. My right hand however remained clutched over the wire it held. The impressions were that I was receiving the current during five seconds or so but this was probably quite a delusion. Under this impression tried hard to shout for help to clear the wires while struggling with that object. Imagined that I was screaming loudly though inarticulately. Was subsequently informed that I had not screamed but only produced gurgling moans, audible however across the engine room among the noise of machinery. Fell slowly over as it has since been described, and as I can distinctly remember on the

right side turning round as I did so under the restraint of the wire grasped in right hand. Fell on right shoulder and back fully over a flump bank, breaking some six or seven lamps. Just about the instant I fell, the pain of the shock left me. Imagined the total time to have been fully five seconds but suppose it was between two and three. In this time many ideas passed through the mind, in particular the consciousness was present that I was getting a high tension shock although it was quite unexpected, and also one or two cases passed through my mind of the further endeavors made by persons receiving heavy shocks to free themselves of connections. Conspicuous was the case read of in the Herald evidence. The moment the pain ceased remember seeing two or three persons hasten forward to my assistance, and recollect their relative approximate positions in the room, they had not moved from their original positions more than a few feet. The next impulse was to free the right hand from the wire it still held. The middle finger was heavily flayed and needed the temporary assistance of the other hand to restore it, when the wire quitted under its own elastic pull. No other ill effect were then felt. Rose to my feet. A rush of perspiration then came to the hands, and I felt that they were slightly scarred. There were blisters on the right hand and a burn deeper than a blister on the knuckle of the left. The mind seemed quite clear and unaffected, but there was some nervousness and an effort was required to prevent the quivering of the under lip. Some sleeplessness was noticed later, and slight nervous pains but nothing of any consequence. There appeared to be a slight difficulty in the first hour afterwards of estimating the weight of any object properly when lifting it in the hand, but this may only have been an imagination. Had no means of knowing the quantity of current that passed through the arms; but although right hand was inside the outside of the left hand would be nearly dry, and therefore the amount was probably very small.

Heating of bobbins for ore milling
Electro magnets by current

The spool described on page gg was subjected for 2 hours to a current of 1.63 amperes its resistance being about 51 ω rising however to about 57 ω = 2.657 × 57 = 151 Watts and the ext. surface is 1065 sq. cms = 7 sq. cms. per Watt. Assisted by convection through the interior this spool in the vertical position became so hot that the hand could just be kept upon it. The surrounding normal temp. was about 25°C.

Another spool was wound as directed on page gg below with 21 w (19½) # 19 SWG s.c. cond. in 18 layers of 120 turns each. With 2.7 amperes through it, the temp. at the surface was to about 50°C. under similar circumstances. The dimensions of the coil are:– ext diam 7" (17.7) int. diam. 5" (12.7) height 7¼" (18½) interflange 7¼" (18.2) Res 28.5 ω – 0.87 = 27.6 ω $\frac{27.6}{27}$ = 1.386 = 100° C increase rise of temp. The ext surface is 18.3 × 3.14 × 18.2 = 1046, and the Watts 201 = 5.23 sq. cms per Watt.

22 lbs. will be wound on these spools instead of 19½. Bringing the heat down to 6.6 sq. cms per Watt.

Tests of Transformer #2.

December 28th 1889.

			Pr.	Sec.
10 o'clock	Commenced running.		7.4 amp.;	18.5v. 300amp 5550w
			Speed 1760	
Noon	stopped.		Highest temp. on armature 70°C.	
13.20	Recommenced		Pr.	Sec.
		light	1050? 1.1 amp 1155 w.	20.5v. 10amp 205w. E 0.18
			Power absorbed in running light 950w	
		Commercial load	1050? 2.4 amp 2520 W.	19.2v. 60amp 1152 w. Ins. 1268 E 0.46
		Load:	1050? 6.8 6834W	17.8v. 275 4895 w Ins. 1935w. E 0.72
17.35	Stopped. Brushes sparking heavily and low volt commutator very hot. Fault in the pressure and contact of brushes. Highest armature temp 75.5°C			

Experiment on the variation in the resistance of iron under magnetic stress.

Upon a strip of wood 7.4 long 7.2 wide and 0.45 thick were wound 80 turns of fine iron wire 0.008" (0.0203) diam., in a width of 5.8 so that the average distance apart was 0.09. The whole strip after winding was dipped in melted paraffine wax. It was then supported between the poles of the large electromagnet in a horizontal position so that the flux would pass along the wire on each side, i.e. the direction of the wire approximately coincided with the direction of the field. The resistance of the wire was then observed by bridge with the current (of about 20 amperes) on and off the magnet. The strength of field was not measured.

With the magnet excited the res. with leads deducted was 31.64 w
" " " disconnected " " " " 31.55 w
Diff 0.09 w.
an increase under mag. stress of 0.285 %

The strip was then set vertical and the poles made to approach until about 0.2 from the strip on each side or about 0.9 from each other. Fiber paper was loosely inserted to keep the strip central. The difference in res. on exciting the magnet under these conditions varied from −1.07% to −0.57% making a mean from 8 observations of 0.92. This reduction was probably due to short-circuiting of the wire under stress, for they could be heard to move under the magnetic influence. The short-circuiting of one pair of wire on one side would produce a difference of about 1%

Measurement made for The Edison Machine Works of the effect of stranding wires on their total conductance.

A strand of seven bare soft copper wires neither bright, nor soiled, six wound helically round the seventh, and each 0·065" = 0·165 diam. was laid upon the floor over a length of 625. Seven similar but unstranded wires were laid near and parallel to it. All were stretched by a cord running over two pulleys to a weight of 40 lbs. (18600), averaging thus 1300 per wire. At the ends wires were led off to the differential galvanometer. The current employed to traverse the stranded and unstranded conductors was about 20 amp. and the deflection on one side of the gal. amounted to some 500 divs.

With the connection points 60 in cms apart on the unstranded wire and 60 in·5 cms apart on the strand the deflection showing extra res: on the unstranded side was 2 divs requiring 10 w to balance $\frac{502}{500} = 1{\cdot}0040$ $\frac{2710}{3700} = 1{\cdot}0038$, a difference of 0·38 %. The weight of the unstranded wire was 810. that of the strand 818·5. The strand diameter was 0·190" = 0·482 and there were just 600 hanks across the axis at one side in the whole length of strand = 100 hanks per wire = 6·0 average distance of one complete revolution i.e. the pitch.

Theory of subject based on the assumption that the wires are tubes of flow i.e. that no current passes from one to another.

Let r be the radius of the unstranded wires (all equal)
p - - pitch of the strand i.e. the distance ~~from~~ measured along the strand axis of one revolution.
θ - - angle of twist, between the strand axis and the orthogonal projection of the axis of an outside wire upon a ~~plane diametral~~ of the strand
l - - length of the strand (axis)
n - - number of twisted wires – usually 6.
m - - - untwisted wires – usually 1.
Then if λ - - length of the untwisted wires in length l of axis
and ρ - - res: of the wires per unit length
c - - conductance - - - - - - $= \frac{1}{\rho}$

we have $\lambda = l \sec\theta$

$$\tan\theta = \frac{\pi r}{p}$$

joint res $R_1 = \dfrac{1}{\dfrac{n}{\rho l \sec\theta} + \dfrac{m}{\rho l}} = \dfrac{1}{\dfrac{n + m\sec\theta}{\rho l \sec\theta}}$

$$= \frac{\rho l \sec\theta}{n + m\sec\theta}$$

But $\sec^2\theta = 1 + \tan^2\theta \quad \therefore \sec\theta = \sqrt{1 + \frac{16\pi^2}{p^2}}$

$$= \sqrt{1 + \frac{4\pi^2 d^2}{p^2}} \quad \text{where } d = \text{diam} = 2r$$

$$= \sqrt{1 + \frac{4\pi^2}{q^2}} \quad \text{where } q = \frac{p}{d}$$

$$\therefore \frac{R_1}{R} = \frac{\rho l \sec\theta}{n + m\sec\theta} \times \frac{m+n}{\rho l}$$

$$= \sec\theta \left(\frac{m+n}{m\sec\theta + n}\right)$$

$$\frac{c_1}{c} = \frac{1}{\sec\theta}\left(\frac{m\sec\theta + n}{m+n}\right)$$

If x be the loss of conductance in

$$x = \frac{100\sec\theta\,(m+n) \mp 100\,n}{\sec\theta\,(m+n)} \quad \text{where } m = 1$$

this becomes $\quad x\,\% = \dfrac{100\,n\,(\sec\theta - 1)}{\sec\theta\,(n+1)}$

$$= 100\,\frac{n}{n+1}\left(1 - \frac{1}{\sec\theta}\right)$$

$$= 100\,\frac{n}{n+1}\left\{1 - \frac{1}{\sqrt{\left(1+\frac{4\pi^2}{9}\right)}}\right\}$$

$$= 100\,\frac{n}{n+1}\left\{1 - \frac{9}{\sqrt{9+4\pi^2}}\right\} = \frac{600}{7}\left\{1 - \frac{1}{\sqrt{\left(1+\frac{4\pi^2}{9}\right)}}\right\}$$

In this case $\quad q = \dfrac{2\cdot36}{0\cdot065} = \dfrac{2360}{65} = 36\cdot34 \qquad q^2 = \dfrac{1321}{1296} \quad \checkmark = 36\cdot89$

$$\frac{0\cdot55}{36\cdot89} \times \frac{600}{7} = \frac{3094}{2989\cdot36} = \frac{330}{258} = 1\cdot28$$

The loss in conductance should have been $1\frac{1}{4}\%$

Concerning the mass of a strand

In length l if w be the weight in grammes per cm. of the wire then

$$nl + nl = W_1$$

$$\therefore\ ml + nl\sec\theta = W_1$$

instrandedness $\quad W = (m+n)\,l$

$$\therefore\ \frac{W_1}{W} = \frac{ml + nl\sec\theta}{ml + nl}$$

where $m = 1$, $n = 6$

$$\frac{W_1}{W} = \frac{1 + 6\sec\theta}{1+6} = \frac{1 + 6\sqrt{1+\frac{4\pi^2}{9}}}{7}$$

$$\frac{100+x}{100} = \frac{1 + 6\sqrt{1+\frac{4\pi^2}{9}}}{7}$$

$$x = \frac{600}{7}\left(\sqrt{1+\frac{4\pi^2}{9}} - 1\right)$$

$$= 1\cdot3$$ practically the same result.

The % loss of conductance in a strand of 7 wire is thus

$$85\cdot7\left(1 - \frac{1}{1+\frac{2\pi^2}{9}}\right)$$

$$= 85\cdot7\left(\frac{2\pi^2}{9}\right) \text{ approx.}$$

$$= \frac{1714}{9} \text{ approximately.}$$

and generally speaking the % loss of conductance is approximately equal to the % excess in weight of the stranded over separate wires per unit length.

(2) That it is possible when the strand is compressed and the component wires are clean, for cross conduction to take place from one wire to another in which case the loss of conductance will be less than the proportionate gain in weight.

Test of # 3 Car Transformer

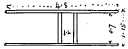
Armature 23. XII. 89

Resistance of a single coil shunted by 95 others 0.017 ω
" " the high tension circuit (brush to brush) 5.85 ω @ 20°C.
Inductance of a single coil shunted by 95 others 0.000160 ω = 1.6 K
" " the high tension circuit (brush to brush) 0.048 ω = 480 K.

The armature was tested lying across wooden horses in air, and its inductance could probably be much greater between the poles of its field magnets. The insulation of the circuits was ok.

Measurement of the change of resistance of iron with magnetisation. Preliminaries could.

A hard rubber spool was taken of the dimensions shown. It was wound with 362 turns of iron wire diam. 0.0105" 0.0266 cond to 0.016" (0.040), in 27 layers averaging 14 turns per layer.



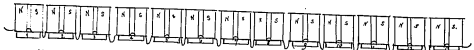
This was supported in ~~approximately~~ two definite positions between the poles 1st with the plane of the coil parallel to the field. 2nd with the plane of the coil at right angles to the field. In the first case conducting the lines of flow to a greater or less extent, the increases of resistance on exciting the magnet was 0.145 ω, 0.155 ω, 0.155 ω, 0.17 ω. Mean 0.155 ω in 12 ω = 0.13 %. In the second case where the coil embraced the lines but only conducted them transversely the effect of exciting the magnet could not be detected, and 0.02 ω or even 0.01 ω could have been noticed.

Determination of the balancing weight for the car motor armature. 30th December. 89

It was ascertained that the weight required to balance the motor armature at 1400 revolutions per min. was

1.75 ounces	at a radius of	6.15" =	10.76 moment
2.3 "	" " "	6.3	14.5
1.0 "	" " "	6.48	6.4
0.25 "	" " "	6.5	1.6
			33.3

If stood in the form of lead poured while liquid into holes at a radius of 3.1" this represents 10.7 oz.


N S N S N S

Experiments on the effect of developing hydrogen upon the surface of immersed steel in diminishing rust.

In the preceding experiment (page 103) no decided effect could be observed after some 20 days duration. The experiment was therefore repeated as follows:—

6 gallon jars were filled with tap water containing $NaCl$ in solution (density 1.027 @ 17°C. In the first two plates of steel 0.012" × 0.03") 3.13" (7.9) broad × 8" long (20.3) were immersed. The backs varnished. Similar plates were immersed in the other jars, the rods forming the anodes. The surface exposed in each cell is about 161 sq. cm. of clean steel. (Backs shellacked)

Jar #1	receives a steady current of 0.016 amperes equivalent to	1 amp per sq. metre
" 2	" " " " " 0.032 "	2 amps per sq. metre
" 3	" " " " " 0.048 "	3 " " " "
" 4	" " " " " 0.064 "	4 " " " "
" 5	" " " " " 0.080 "	5 " " " "
" 6	no current	

The current was sustained by 5 separate Bunsen cells.

On the Winding and Testing of the One Milling Magnets described on page 119.

The iron core was wound with 22½ lbs of #8 D.C.C. wire in 4 layers and a half. It was then taped and copper sheeting ⅛" thick laid over it and soldered. A coating of black carpenter's varnish was ~~placed~~ given over all. A current of about 31 amperes was then applied for 3 hours. At the end of that time the hand could be kept on the surface.

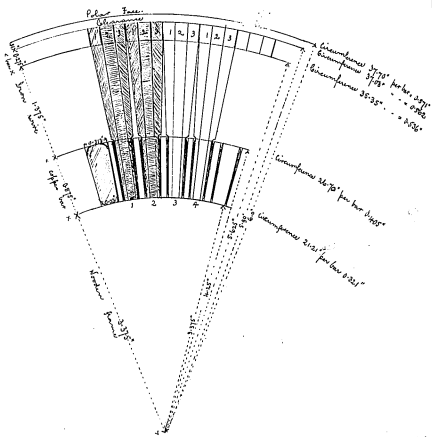
The res. of the magnet + leads was then 0.1608 = 0.1353
Next day after cooling " " " " " 0.1325 = 0.1070
leads 0.0255

The rise of res. was 0.1353 − 0.1070 = 0.0283 = 26.5%
÷ 0.38 = 70°C rise.

The same wire was wound (9.5.90) on a core just twice the length, in 2½ layers.

Particulars of new pattern armature for the ~~Street~~ Bar motor.

The armature made as described on pages 60 and 87 presented considerable difficulty in setting together the larger wires and soldering their ends to the commutator. The design was therefore changed in favour of a bar armature of lower peripheral speed, with brushes on its surface and no separate commutator.



Lower bars to be formed of 7/8" x 5/16 (0.875" x 0.313") bar with rounded edges slots in the ends of these for solder cups 0.5" deep 0.23" wide.

Upper bars to be triple.

Each component strip to be 0.275" high above and 0.5" at sides.

Breadth (plate thickness) 0.162"

Mica between each pair of component bars 0.005" or 0.007 above

" " " " " main " 0.014" beneath or 0.06" above.

Particulars of the Behavior of a Chatillon Steel Spiral Spring under experimental test.

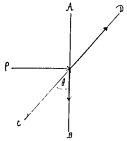
31. 12. 89.

The spring is a single spiral of 3/8" steel wire of 15 turns, its length when all parallel to the axis being 9 3/8" before and after having been closed 9 1/16" (permanent set of 5/16"). The ends are flattened to a plane perpendicular to the axis. The outside diameter of the spiral is 2 7/8", the internal 1 7/8" and the distance separating adjacent spires in relaxed state 1/16". On first compression the following were the observed stresses :—

No. of Exp.	Length of Spring	Compression	Weight suspd.
1	8 2/3	1"·0	190
2	7 7/8	2·0	360·5
3	7 3/8	2·5	452
4	6 7/8	3·0	530
5	6 3/8	3·5	599
6	5 7/8 spires touching	4·0	665

Mathematical Analysis of the Efficiency of Worm Gearing.

It is assumed that the teeth of the worm and worm wheel to engage that sliding friction only is brought into play without bind, i.e. that the teeth are properly shaped + fitted



Let AB be a line parallel to the axis of the worm. Let P be a force applied in the worm's plane of rotation against the teeth of the worm wheel. Let θ be the angle of transmission of the worm, and CD the line representing the pitch surfaces engaged.

Now suppose the force P to advance through a distance d, in doing which the work done will be Pd. The advance of the worm tooth will have necessitated an advance of the worm wheel tooth through a distance $d \cot\theta$ in the wheel plane of rotation and if Q represent the power exerted by the wheel at the pitch line, the work done will be $Q\, d \cot\theta$. The normal stress across the pitch line will be $P\cos\theta$ due to the effect of P diminished by $-Q \sin\theta$ owing to effect of Q so the tangential friction is $\mu(P\cos\theta - Q\sin\theta)$ and the component of d in this direction is $\frac{d}{\sin\theta}$ so that the work done against friction $= \frac{\mu d}{\sin\theta}(P\cos\theta - Q\sin\theta)$

Hence $Pd = Q\, d \cot\theta + \frac{\mu d}{\sin\theta}(P\cos\theta + Q\sin\theta)$

or $P(1 - \mu\cot\theta) = Q(\cot\theta - \mu)$

$$\frac{P}{Q} = \frac{1 + \mu\tan\theta}{\tan\theta - \mu} \qquad \text{Taking } \mu = \tan\varphi$$

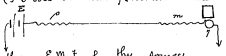
$$= \frac{\cos\theta\cos\varphi + \sin\theta\sin\varphi}{\sin\theta\cos\varphi - \cos\theta\sin\varphi} = \cot(\theta - \varphi)$$

Experiments with the Phonograph Motor for the purpose of driving a sewing machine 1st–5th Jany. 20.

Used a small Singer sewing machine with the treadle disconnected, driving from an ordinary phonograph motor with an extra large pulley on its shaft directly by a round belt to the sewing machine shaft pulley. The velocity ratio was about 2. — 8 Phonograph Nº 140 cells.

No	Revs. per min Armature	Revs. per min Singer	Density	Obserb.	Amperes	P.D. at Motor terminals	P.D. at battery terminals	EMF of batty. cells	Approx. EMF of motor	Power generated in armature	Lost Watts in battery	Lost Watts in motor	η
1	240	480	Running off	1·3	6·67	2·5	3·1	6	1·03	41	23·3	9·8	
2	325	650	" "	1·35	6·92	2·85	3·22	"	1·08	41·5	21·8	12·3	
3	0	0	hold	1·76	9·03	2·0	"	6	0	54	"		
4	314	628	light	1·3	6·67	3·0				40			
5	192	384	working off	1·55	7·95	2·5			"	47·7			
6	282	564	" off	1·4	7·18	2·75				43·1			
			Res: of	battery	0·435	= 0·054	per cell		Res. leads 0·09 in (1) + 0·056 in rest + motor (joint) 0·22				

But separately exciting the magnets from the 110 volt circuit ascertained that up to 2·18 amperes in the field the speed increased, so that at this point (3·6 volts at motor terminals the efficiency should be 0·50)



Let E = the E.M.F. of the source
ρ = res. " " " " leads
m = " " " " motor
η = e.m.f. " " armature.
c = working current
f = effective forces due to magnetic mechanical frictional work referred to the periphery of the armature
r = radius of armature
n = revolutions per min:
ϕ = Total flux magnetically traversing armature.
N = Number of wires all round sector. ($\frac{1}{12}$ circle)

Then $\frac{E-\eta}{m+\rho} = c$ and $\eta c = 2\pi n r f$ and $\eta = \phi N n 10^{-8}$

From these eliminating c

$$n = \frac{E\phi N 10^{-8} - (m+\rho)2\pi r f}{\phi^2 N^2 10^{-16}}$$

$$\frac{dn}{df} = -\frac{E}{\phi^2 N 10^{-8}} + \frac{2(m+\rho)2\pi r f}{\phi^2 N^2 10^{-16}}$$

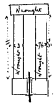
for max: $\frac{E}{\phi^2 N 10^{-8}} = \frac{4\pi r f (m+\rho)}{\phi^2 N^2 10^{-16}}$

or $c = \frac{1}{2}\frac{E}{(m+\rho)}$

$\therefore \eta = \frac{E}{2}$

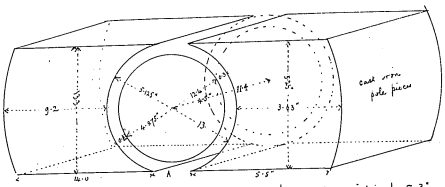
So that for separately excited field magnets the speed of rotation of the motor armature will be a maximum when all other conditions remaining constant the counter emf is just half the source EMF and or when the efficiency is 0·5 and the work done a maximum.

When wound the fields had 9½ layers of 355 turns = 3400 turns.



When complete the field measured 1920 (both coils in series) @ 20°C.
" armature " 1.4400

Speed 2830 revs per min. @ 110 volts p.d. = 2770 ft per min. = 1890 r.p.m.
Current in field 0.57 ampere, in armature running light 0.66 ampere.
Watts 65 73 Watts



The bore of the field was increased to admit winding to 5.3" (13.5) and the distance between polar heads 2.2" (5.6) at A.

Field winding
6 lbs # 26 B.W.G. 0.018" in all or 3 lbs. on each limb.
about 11 layers of 300 turns.

Armature winding
30 divisions separated by 0.025" of paper and fiber
1 wire 10 turns round in each division.
300 complete turns of drum. #28 B.W.G. 0.0320" d.c.c.
With paper 0.03" and wire 2 layers 0.14" = 0.19" + 0.1" = 0.29" clearance
This will necessitate boring out the poles to 5.44", and will practically double the reluctance.
1 turn of armature = 1.5" approx. 1 75 × 1.5 = 112.5" @ 0.0043 = 0.485 Ω
say 0.5 Ω.
24.600 c.mils should allow 8 amperes through armature = 800 Watts
absorbed practically 1 H.P.
The weight of wire on armature = 3.80 lb.
The weight of the bores with pole pieces 92 lbs. yoke 50 lb.
Speed less than 2000 ft per min.
Field radiation 20 sq. cms per Watt. 200 w total rad.
Periphery of armature over bands 5.13" (13.1) = 15.92" circum = 1.33'

Loss in armature. 0.5 × 11.4 × 6.2 × 6.2 = 351 c.c.
Hysteresis dissipation rate @ 2830 revs per min = $47.1 \times 2 \times 351 \times 10^{-3}$ Watts = 33

Calculations for the Winding of a Small Motor of Dimensions shown P.D. 100.

This motor though intended to run off the 110-volt circuit will probably be operated with lamps in circuit. The field magnet may be connected however directly. We may assume a velocity of 2000 ft per min (1000 cms. per sec) at 50 volts counter emf and take any lower desired speed by lamp adjustment.

The rel. of the air gap is $0.3/18 \times 11.4 = \frac{0.3}{205.2} = \frac{3.0}{2.05} \times 10^{-3} = 1.47 \times 10^{-3}$

The cross section of the armature is 12.4 × 11.4 = 140 sq. cms. @ 10,000 lines = 1,400,000 lines required and the cross sectional area of the limbs are 45 sq. cms @ 10,000 lines = 450,000. Say 500,000. of these say 30% or 150,000 will be lost by leakage leaving 350,000 for service. A speed of 1000 cms per sec. with a periphery of 12.7π = 40 cms. gives 25 revs per second.

$$\therefore \quad N = \frac{50 \times 10^8}{3.5 \times 10^4 \times 2.5 \times 10^{-3}} = \frac{5.0 \times 10^8}{0.875 \times 10^3} = 572$$

Taking 600 wires all round the circumference + 24 divs = 25 wires to each division, or 30 divisions and 20 wires to each division.
The circumference of the armature is 12.4π = 39.0 cms. 15.3". 30 fibres each 0.025 = 0.75" leaves 14.55". This leaves 0.14555 for the diameter of the covered wire and allowing 0.015" for the total thickness of covering makes 0.130 for the wire. The nearest size smaller than this is # 28 B.W.G. 0.0320". Thus three layers of such wire will not fit into the space between the pole and armature.
If wound for 100 volts there will be 1200 wires all round and 40 wires to each division = 20 wires to each layer = 0.024" overall = 0.0768 covered say # 26 B.W.G. 0.0404" as nearest size = 19.60 c.mils
It remains to determine the field winding.
This may be 0.33" deep = 0.8 cms. The external diam. will then be 9.2 cms. and the annular area $\pi(9.2^2 - 7.8^2) = 26.5$ sq. cms. = 21.6 sq. cms. and the length 27 cms = 58.3 sq. cms. on each limb. The heat radiated may be 20 sq. cms per Watt = 29.6 Watts = 60 Watts in all from both limbs @ 110 volts = 0.55 amperes = 200 w. in all (hot) = 95 w on each limb coil.

$$d = -0.02 + \sqrt{0.00004 + 0.00153\left(\frac{590}{95}\right)}$$

$$0.00153\sqrt{6.10}$$

$$0.00153 \times 2.47$$

$$0.00378 = 3.78 \times 10^{-3} \quad 37.8 \times 10^{-4}$$

$$41.8 \times 10^{-4}$$

$$6.47 \times 10^{-2}$$

$$= -0.02 + 0.065$$

$$= 0.045 \text{ cms} = 0.018" \quad \#24 \text{ B.W.G.}$$

Covered = 0.023" and in 1 layer there will be 300 turns.
In 0.33" there will be 10 layers and the mean circumference $\frac{8.6 \times \pi}{2.54} = 10.17" = 0.85' + 3000$ turns = 2550 feet @ 0.032 Ω = 81.6 Ω.
If # 27 wire be used (0.016" covered to 0.031") there will be 330 turns per layer + 11 layers = 3630 turns = 3085' @ 0.04 = 12 Ω.
24 = 9 Ω @ 0.0208 lbs per Ω = 2.93 lbs can therefore be placed on each limb. = 6 lbs. in all. # 26 B.W.G. This will give 6000 × 0.55 = 3300 A.T. = 4100 exciting m.m.f.

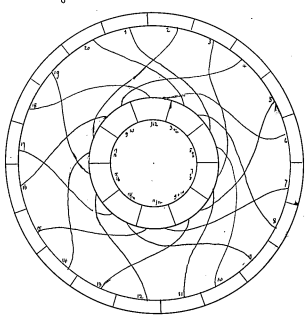
$$\frac{4.100 \times 10^3}{1.47 \times 10^{-3}} = 3 \times 10^6 \text{ lines produced, or considerably beyond saturation}$$

Exp 3rd go. On trial machine gave 110.5 v. @ 2830 revs.

$$\therefore \phi \times 600 \times 47.1 = 1.135 \times 10^{10} \quad \therefore \phi = \frac{1.135 \times 10^{10}}{2.826 \times 10^4} = 402{,}000.$$

6 turns of wire round respect. gave 250 divs of ballistic g. on revs = 110 (for flux thru 5.5,000 0.4064) changed by 1.43 ⁺ (2.40 × 10¹⁰ × 1.43 × 10⁻⁸ = 0.5797 × 10¹⁰ g) produce 62 divs ∴ 1 div = 9.31 × 10⁸ g.
$\phi = 140 \times 10^8 \times 5.53 \times 10^{10} \times 9.31 \times 10^{-8} \times 72.0 \times 10^{-8} \div 6 = 1.201 \times 10^{10} = 1{,}200{,}000$

When rewound as shown the highest temperature shown by thermometer on the armature was 165°F (74°C) after running for one hour though a strong field (excited direct from 135 volt) generating over 8 volts (without brushes).



Particulars of a Test made of the effect of Electrical Endosmose upon the reduction of uric acid calculi in a gouty patient.

16th to 30th Dec. 1889.

The person submitted to this experiment was H. E. Ritter of Moorbleam N.J. aged 73½, who has had an active Gouty Disease was contracted 8 or 10 years ago, and according to patient's statement through sleeping in damp sheets. These calculi commenced at that time & slowly increased until about 4 or 5 months ago when pain commenced apparently from the pressure upon the nerves. There was also noticeable a certain degree of venous congestion in the face attributable to impeded circulation. All the joints except the knees were greatly enlarged by calculi. Thus the girth of the little finger of the left hand was 8.6 cms. and that of the corresponding finger right hand still larger. Great weakness and difficulty in walking. Mind clear and intelligence unimpaired.

Treatment commenced on 16th December with 13 mas. for one hour left hand in $LiCl$ solution density 1.08 up to the ulnar condyle. Right hand immersed in $NaCl$ solution 1.05. Current entered at left hand thus tending to carry $LiCl$ into the tissues. Treatment continued for about four hours daily until 21st Dec. with 20 mas. (110 volts through 90 + galvs.). On that date the measurement of the left hand little finger calculus was 8.2 cms. Treatment continued from 23rd to 24th inclusive. On last day solution exchanged for 1% Li_2O_2 which blistered the hands of the patient in some degree. Patient then discontinued treatment. On 31st Dec. the girth was 8 cms. showing a total reduction of 0.6 cms which was deemed conclusive evidence of beneficial effect. Patient also felt better during treatment the pain in joints ceasing and general amelioration felt by him, that continued journeys to and from laboratory after three years total inactivity had exhausted his strength.

Rewinding of Low Volt Armature.

The great heating of this Z 1000 ampere armature, at very low magnetic densities, apparently owing to foucault current, rendered it necessary to rewind the armature. There are 10 commutator bars and 20 divisions of the armature. In each division were 16 # 9 S.W.G. wire 0.1148" The whole mass had suffered very greatly from overheating. It was rewound with 16 braided # 7 B.W.G. 0.1444 S.C.C. The winding was "side by side" as shown on the opposite page. The diam. of the body over insulating paper is 9¼" (9.7" 246.6 cms.) The length of the body = 10.75" = 27.3. The mean length of one turn will be about 3.5 feet. The effective length of wire on the armature is thus $\frac{3.5 \times 20}{16 \times 10} = \frac{70}{64} = 1.09$ ft

0.0005 ω per ft = 0.000055 ω.

Problem:- To determine the winding of a motor when the work it has to do is stated, and when the magnetic circuit and winding space are outlined

First neglect the field circuit and leave it as a separate consideration

let n be the number of revolutions of the armature per sec:
" w - - - - active wires all round armature (gramme ring)
" φ - the flux $\times 10^{-8}$
" ε - - counter emf of the motor.
" W - - work required from the motor including its own mechanical and electrical friction.
" b - - resistance of the source of emf & its leads
" E - - emf. of the source
" l - - mean length of one turn on the armature (gramme ring)
" K - - total coiling space occupied
" ρ - - mean resistivity of this space
" r - - res: of the armature.
" c - - current strength in the armature.

Then the length of wire round the armature $= wl$

" section of the winding $= \frac{K}{l}$

" section of each wire $= \frac{K}{l} \div 2w = \frac{K}{2wl}$

" resistance of the wire all round $= \frac{2wl\rho}{K}$

" " " " armature " " $= \frac{w^2 l^2 \rho}{2K} = m = \beta w^2$
$= w^2\left(\frac{l\rho}{2K}\right)$ where l = length of winding (gramme ring)

$$\frac{E-e}{b+m} = c \qquad \therefore \frac{c(E-e)}{b+m} = cc = W.$$

$$\therefore \left(\frac{E-\varphi n w}{b+\beta w^2}\right)\varphi n w = W.$$

$$\frac{dW}{dw} = \varphi n\left(\frac{E-\varphi n w}{b+\beta w^2}\right) + \varphi n w\left\{\frac{-\varphi n(b+\beta w^2) - 2\beta w(E-\varphi n w)}{(b+\beta w^2)^2}\right\}$$

for a maximum W with w as independent variable.

$$(E-2\varphi n w)(b+\beta w^2) = 2\beta w(Ew-\varphi n w^2)$$

whence
$$w^2 + 2w\frac{b\varphi n}{E\beta} = \frac{Eb}{E\beta}$$
$$w + \frac{b\varphi n}{E\beta} = \sqrt{\frac{E^2b\beta + b^2\varphi^2 n^2}{E^2\beta^2}}$$
$$w = -\frac{b\varphi n \pm \sqrt{E^2b\beta + b^2\varphi^2 n^2}}{E\beta}$$

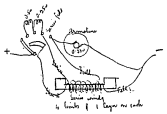
since $b\varphi n$ is usually small in comparison with $E^2b\beta$ we have
$$w = \sqrt{\frac{b}{\beta}} = \sqrt{\frac{b}{\frac{l\rho}{2K}}} = \frac{1}{l}\sqrt{\frac{2Kb}{\rho}} = 2\sqrt{\frac{Kb}{l\rho}}$$

Finally since $\frac{l\rho}{K}$ is the res: the armature would have if all its wires of whatever sizes were in parallel - made one complete turn call this res: R. Then $w = 2\sqrt{\frac{b}{R}}$, and the res: of the armature will then be $\frac{w^2R}{4} = b$.

The current c will then be $\frac{E-e}{2b}$ energy lost in battery $\frac{E^2}{4b} = \frac{E^2}{16b}$ 25%

and for max: work $\frac{E}{2b}$ " " " armature $\frac{E^2}{16b}$ 25%

" maximum work W: $\frac{E^2}{8b}$ 50% " developed $= \frac{E^2}{4b}$



When rewound the armature had a resistance of 0·33 ω
ie: 2 each of 6 turns 0·07 ω
" " " dia: 0·14 ω
as wound, previously. . . . 0·10 ω
present size of armature wire ⌀ 23 B.W.G 0·025"
four layers of 9 turns each = 36 wire per dia.
360 wire per sector.

The fields have 7 layers of 30 turns = 210 turns each.
and the limbs have now a section of 2" × 2" = 1·290 sq. ins.
4·20 turns to each pair of coils.

Still later a series winding has been applied to fields in the armature circuit to help the motor in starting. 1 layer of 30 turns same wire on each limb and all four in parallel = 0·063 ω

Battery 10 double plated cells of R.H.S type.

Machine works satisfactorily.

Application of formulae on preceding page to the determination of the winding of the phonograph motor in sewing machine.

The resistance of battery and leads = 0·45 ω and if the armature be made equal to this the current flowing at maximum work will be $\frac{5.6}{2 \times 0.9} = \frac{6.2}{2} = 3.1$ amperes taking each cells emf. as 0·7 volts. The energy delivered will then be $\frac{5.6 \times 6.2}{2} = 8.68$ watts out of which at least 50% should be utilised after deducting mechanical and electrical frictions. The resistance of the armature is at present 0·25 ω so that it has to be increased to 0·45 ω or as the square root of 1·8 = 1·342 and this represents 80% ~~16 B.W.G~~ c. mils. or ⌀ 23 wire B.W.G. ~~now~~ size smaller than at present. For place of 3 layers of 9 turns there will be 4 layers of 10 turns.

General "Data" connected with winding apparatus.

Having a given winding space κ of resistance r when wound with a certain length l of wire in w turns the diameter of the wire being d its resistivity ρ, the thickness of insulation being t, the supply e.m.f. at terminals E and the current c, then the section of the wire being s the apparent resistivity of the space is

$$\rho_1 = \frac{\kappa r}{l s} = \frac{r(d+2t)^2}{l}$$

but $\rho = \frac{\pi r d^2}{4 l}$

$$\therefore \rho_1 = \rho \frac{4}{\pi}\left(\frac{d+2t}{d}\right)^2 = \frac{4\rho}{\pi}\left(\frac{D}{d}\right)^2 = 1.273\rho\left(\frac{D}{d}\right)^2$$

for pure copper $\rho = 1600 = 2088\left(\frac{D}{d}\right)^2$ @ 0°C.
" 98% " $\rho = 1670 = 2130\left(\frac{D}{d}\right)^2$ @ 0°C.
$= 2200\left(\frac{D}{d}\right)^2$ @ 20°C.

$$r = \frac{w \tau \rho_1}{D^2} \quad \text{where } \tau = \text{mean length of turn}$$

$$\kappa = w \tau D^2$$

$$\therefore r = \frac{\kappa \rho_1}{D^2}$$

$$c = \frac{E D^2}{\kappa \rho_1} \quad \text{Heat}$$

$$f = \frac{E^2 D^2}{\kappa \rho_1} \quad \text{Number of turns}$$

$$w = \frac{\kappa}{\tau D^2}$$

$$cw = \frac{E D^2}{\tau \rho_1} \quad \text{Ampere = turns.}$$

Field winding determination for Sewing Machine Motor

There are about 135 turns of wire on each limb of field = magnet and 1·8 amperes are required to effectively charge field = 243 ampere = turns say 250. To employ only 1 ampere there must be 250 turns ~~but~~ 62 turns on each limb. With maximum work energy the RD on MT should be 0·75 × 5·6 = 4·2 volts. so that the resistance of field must be 4·2 ω in all or 1·05 ω per limb for 250 turns. The mean turn would be about 24 cms long = 0·8" so that 250 turns = 200 ft say 200 ft long. 1000' would thus offer 5·25 ω. = 0·0052 ω per ft = ⌀ 29 B.W.G.

When the armature is at rest the current flowing through it will be 6·2 amperes and 2·8 volts will be at the terminals. This will give only $\frac{250 \times 6.2}{2}$ A.T. to the each pair of fields (333) instead of 500, so that 167 must be supplied by 6·2 amperes = 25 turns = 12 turns on each limb (series winding)

Taking the sp. g. of matte as 5.0, the weight of a plate 3" x 3" x 1" is 235 lbs.

18 sq. feet	thus weigh	235
1 "	— "	13
286,800 "	— "	3,730,000 lbs
		= 1,665 tons.

Each plate occupies say 3" breadth (1" + 2") = 0.25' and 7170 sq. ft in each bath = 398 plates say 400 so that the length of the tank would be 100 ft

The building would be 40 x (3 + 5) = 200 ft long
× 125 = feet

Measurement of the Resistance and Counter Electro Motive Force of a cell containing a copper plate and a coal matte plate.

g. 290

The plates rested in a trough containing solution 5% H_2SO_4. The backs and sides of the plates were varnished with a solution of g.p. in $CHCl_3$. The breadth of the copper plate was 5.5 bent in a rough sector to the matte plate which was 2.5 broad about 10 long and 0.8 thick. The depth of immersion was 6.0 so that 15 sq. cms of matte + 33 sq. cms of copper were active. The distance apart was about 3 cms. The resistance of this cell was approximately 1 ω (Ω) and the res: to d.c. 8.8 so that the counter emf to the current through the cell 0.07 amps. would be 7.8 × 0.07 = 0.55 volts. The temperature was 17°C. in the solution. The cell was then raised to a temp: of 109°C. and the res: was about 0.5 ω. The counter emf about ~~0.5~~ = 0.5 × 0.07 = 0.42 volt

Repeated experiment with a plate of matte exposing 5" (12.7 cms) breadth × 3" (7.6 cms) depth = 15 sq. in = 96.5 sq. cms. area and a copper plate 6" (15.2 cms) × 3" (7.6) with paraffined back

at 20°C.	when separated by	6.3 cms (2½")	res: 0.08 ω	emf 0.23 v.
		3.2 " (1¼")	0.04 ω	" 0.2 v.
@ 50°C.	" "	6.3 " (2½")	0.01 ω	" 0.12 v.
	" "	3.2 " (1¼")	0.02 ω	" 0.12 v.

Taking 100 sq. cms as offering 0.02 ω @ 120°F (50°C) @ 3 cms dist:
36" sq. = 936 sq. in = 6040 sq. cms. 5 sq. cms offer 1 ω suppose
then 6040 " offer $\frac{5}{6000}$ ω = $\frac{1}{1200}$ ω

Problem.

For 12 tons = 1.219×10^7 grammes daily @ 0.5 g (½ theoretical value) grammes per ampère hour = 2.066×10^7 ampère hours daily in 40 baths = $\frac{206.6 \times 10^5}{40}$ = 5.17×10^5 ampère hours daily per bath

= $\frac{5.17 \times 10^5}{24}$ = $\frac{51.7 \times 10^3}{24}$ = 2.15×10^3 = 21,500 ampère hours

whole 24 hours.

The area of matte in each bath @ 3 ampère per sq foot = 7170 sq. ft, and with sheets 36" sq. = 9 sq. ft = 800 plates. In single row this means tank length 800 ft
- double " " " " " 400 "
- triple " " " " " 270 "
- quadruple " " " " " 200 "

The res: per sq. ft will be say 0.01 ω = 100 mhos conductance.
7200 sq. ft will have 720,000 mhos.
e.m.f. due to conduction $\frac{21,500}{720,000}$ = 0.03 volts.
Power absorbed 0.03 × 21,500 = 645 Watts in each tank.
1 " " in counter emf 0.42 × 21,500 = 9,030 Watts in each bath
Total power 360,000 Watts including 10% for bath + dynamo
$\frac{360,000}{3,960,000}$ Watts = 5280 HP electrical
@ 95% eff: = 5000 HP. mechanical.

Formulae for wiring Motors.

Let D be the distance of the motor from the source cms.
E . . pressure . . source
P . . power . . motor in Watts.
η . . efficiency . . .
d . . diameter . . conductor in cms
ρ . . resistivity . . . . ohms.

Then $\frac{P}{\eta}$ is the power to be supplied

Let p be the % of fall emf allowed in leads

Then $E\left(\frac{100-p}{100}\right)$ is the emf at motor terminal

and the current $C = \frac{P}{E\eta}\left(\frac{100}{100-p}\right)$

The resistance of the leads $= \frac{8D\rho}{\pi d^2}$

" fall of potential $= \frac{8CD\rho}{\pi d^2}$

$\therefore \frac{8CD\rho}{\pi d^2} = \frac{pE}{100}$ or $\frac{8D\rho P}{\pi d^2 E\eta}\left(\frac{100}{100-p}\right) = \frac{pE}{100}$

whence $d^4 = \frac{8D\rho P\,(10{,}000)}{\pi E^2\eta\, p\,(100-p)}$ with $\rho = 1{\cdot}78\times10^{-6} = \frac{14{\cdot}53\times10^{-6}DP}{E^2\eta\, p\,(100-p)}$

for $p = 1$	$d^4 = 4{\cdot}576\times10^{-4}$	
" " $= 2$	$= 2{\cdot}312\times10^{-4}$	
$= 3$	$= 1{\cdot}612\times10^{-4}$	
$= 4$	$= 1{\cdot}180\times10^{-4}$	
$= 5$	$= 0{\cdot}9536\times10^{-4}$	
$= 6$	$= 0{\cdot}8032\times10^{-4}$	

$\times \frac{DP}{E^2\eta}$

D in cms P in Watts
E in volt + η in decimal.
d^4 in sq cms.

To express d in sq cms with D in metres $d^4 = 4{\cdot}576\times10^{-2}\,\frac{DP}{E^2\eta}$

" " " " " D in feet $d^4 = 4{\cdot}576\times10^{-2}\times30{\cdot}48\,\frac{DP}{E^2\eta}$

" " " sq inches . D " " $d^4 = \frac{4{\cdot}576}{6{\cdot}452}\times30{\cdot}48\times10^{-2}\,\frac{DP}{E^2\eta}$

$= 21{\cdot}693\times10^{-4}\,\frac{DP}{E^2\eta}$

$= 0{\cdot}002169\,\frac{DP}{E^2\eta}$

circ. mil

$= 0{\cdot}0027574\times10^{6}$

$= 27574\,\frac{DP}{E^2\eta}$

for $E = 220$ $= \frac{27574}{49284}\,\frac{DP}{\eta}$

$= \frac{746\times27574}{49284}\,\frac{DP}{\eta}$

for 1% drop	$= 41{\cdot}71$	$\frac{DP}{\eta}$
" 2% "	$= 21{\cdot}8$	$\frac{DP}{\eta}$
" 3%	$= 14{\cdot}7$	"
" 4%	$= 10{\cdot}76$	"
" 5%	$= 8{\cdot}70$	"
" 6%	$= 7{\cdot}32$	"

On the Matthiesson Standard of Conductivity in Copper

Matthiesson's original unit was 1 standard english mile of pure annealed copper wire 1/16" diam. @ 15·5°C.

Let ρ be the resistivity of this copper

Then $\frac{4 \times 1 \cdot 6093 \times 10^5 \rho}{\pi (0 \cdot 0625)^2 \times 6 \cdot 4516} = 13 \cdot 59$ B.A. units

$\therefore \frac{6 \cdot 4372 \rho \times 10^5}{7 \cdot 9173 \times 10^{-2}}$

$$\therefore \rho = \frac{13 \cdot 59 \times 7 \cdot 9173}{6 \cdot 4372} \times 10^{-7} =$$

$$= 1 \cdot 6715 \times 10^{-6} \quad @ 15 \cdot 5° \; @ 0 \cdot 388 = 6 \cdot 015$$

$$= 1 \cdot 6715 \div 1 \cdot 0602 \times 10^{-6}$$

$$= 1 \cdot 5766 \times 10^{-6} \text{ B.A. ohms}$$

$$= 1 \cdot 559 \times 10^{-6} \text{ Legal ohms.}$$

Jenkin gives the value $1 \cdot 616 \times 10^{-6}$ B.A. ohms in his book p. 251 but the table is calculated from lead through sp. gravity.

Taking the values resistance of a wire 1 metre long weighing 1 gramme as 0·1469 legal B.A. ohms (pure hard drawn copper)

$= 1 \cdot 5795$ Legal $= 1 \cdot 5935$

We have 1 c.c. of pure copper being 8·95 grammes

1 c.c. of diameter d weighs $8 \cdot 95 \frac{\pi d^2}{4}$

100 " " " d " $\frac{895}{4} \pi d^2$

$= \frac{2811 \cdot 72}{4} d^2$

$702 \cdot 93 \, d^2$

$\therefore 702 \cdot 93 \, d^2 = 1$

$\therefore d^2 = \frac{1}{702 \cdot 93}$

$$\frac{4 \times 100 \rho \times 702 \cdot 93}{\pi \quad \pi} = 0 \cdot 1469 \text{ B.A.}$$

$$\therefore \rho = \frac{3 \cdot 141593 \times 1 \cdot 469 \times 10^{-1}}{28 \cdot 11172 \times 10^{-5}}$$

$$= 1 \cdot 6415 \text{ B.A.} \times 10^{-6}$$

$$= 1 \cdot 6234 \text{ Legal} \times 10^{-6}$$

The values taken by Dr. Fleming in the "Electrician" vol XX page 471 # 512 is 1·6244 Legal microhms. for annealed copper.

The values taken by A. Gray Table 1 in Abs. Meas. is the last calculation Sandiling in $1 \cdot 6242 \times 10^{-6}$ B.A. ohms

$= 1 \cdot 6244 \times 10^{-6}$ Legal.

$1 \cdot 6195 \times 10^{-6}$ Imperial

Jamieson's Pocket-Book gives two values :-

1st Matthiessen's standard = Res: of annealed soft copper @ 0°C = 0·02057 B.A. ohms for wire 1 metre long and 1 mm: in diam.

$$\therefore \frac{100\rho}{\frac{\pi}{4}\,0{\cdot}01} = 0{\cdot}02057 \qquad \therefore \rho = \frac{0{\cdot}785398 \times 2{\cdot}057 \times 10^{-4}}{1{\cdot}0 \times 10^{3}}$$

$$\therefore \rho = 1{\cdot}6156 \times 10^{-6} \text{ B.A. ohms}$$

$$= 1{\cdot}5977 \times 10^{-6} \text{ Legal ohms}$$

$$= 1{\cdot}57135 \times 10^{-6} \text{ True "}$$

2nd Matthiessen's standard

Res: of 100" of pure annealed soft copper wire weighing 100 grains @ 60°F = 15·5°C. = 0·1516 B.A. "

$$@\ 0°C = \frac{0{\cdot}1516 \times 0{\cdot}2064}{0{\cdot}2190}$$

$$= 0{\cdot}142288 \text{ " @ } 0°C.$$

2·540 cms weigh 0·0648 grammes.

1 cm weighs $\frac{0{\cdot}0648}{2{\cdot}540}$ "

$= 0{\cdot}025511$ "

but 1 cm: if its section were 1 sq. cm: would = $\frac{8{\cdot}90}{8{\cdot}95}$

$\therefore$ the section was $\frac{0{\cdot}025511}{8{\cdot}90}$ or $\frac{0{\cdot}025511}{8{\cdot}95}$

$$\text{and } \rho = \frac{0{\cdot}142288 \times 2{\cdot}5511 \times 10^{-2}}{2{\cdot}074 \times \frac{8{\cdot}95}{8{\cdot}90} \times 10^{3}}$$

$$= \frac{0{\cdot}364504}{22730} \times 10^{-4} \text{ or } 22605$$

$$= 1{\cdot}6041 \times 10^{-6} \text{ or } 1{\cdot}6120 \times 10^{-6} \text{ B.A.}$$

$$= 1{\cdot}5881 \times 10^{-6} \text{ true or } 1{\cdot}5969 \times 10^{-6} \text{ Legal}$$

Jamieson's	tables	p. 1946	gives	soft copper	1615 true = 1620 Legal	
				hard "	1642 true = 1647 "	
Everett's	tables	gives	p. 159	soft copper	1584 Legal 1580 Imp.	
				hard drawn	1620 " 1616 "	
Anthony & Brackett		give	p. 504	pure copper	1611 C.G.S.	
Houston's	Dictionary	gives	p 531	from Matthiessen's results		
				soft copper pure	1·597 Legal ×10⁻⁶	
				hard " "	1·632 " "	
Mascart	gives	p. 748		soft copper pure	1·584 Legal 1580 Imp	
				hard " "	1·624 " 1617	

Magnetic Susceptibility of three samples of Iron ore. Rough comparison.

13.5.90.

Three samples of sulphide iron ore from Evans Copper cliff and Stobie mines were pulverised & sieved thro' 60 mesh. They were then slightly mixed with water to render the powder cohesive, and portions of ~~the~~ each pressed in a hydraulic mould to cylinders of 2.5 cms diam: and about 6 cms long. A magnetometer was mounted with two solenoids one on each side of it and the zero adjusted until 0.5 ampere passing through the two solenoids gave rise to no disturbance of the needle. The cylinders were then introduced into one solenoid. The mean deflections were

Stobie 3.5 Evans 1.0 Copper Cliff 0.75

On the Field winding necessary for the motor described on the next page.

Let 50 lbs. of copper be used on each limb.

Let x be the ext: diam: of winding, d the internal and l the length of the cy. of the winding. $= 0.75 \times 8.9 = 6.67$

Then $0.7854\,(x^2 - d^2)\,l\sigma = 22680$

$$x^2 = \frac{0.7854\,l\sigma d^2 + 22680}{0.7854\,l\sigma} = d^2 + \frac{22680}{0.7854\,l\sigma}$$

with $l = 25$

$$= (15.2)^2 + \frac{22680}{7.854 \times 10^{-1} \times 2.5 \times 10^{1} \times 6.67}$$

$$+ \frac{22680}{131} =$$

$$231 + 173$$

$$= 404$$

$x = 30$ Depth of winding 1" including insulation

Assume the average p.d. upon the coils considered as shunt coil to be 1½ volts and the p.d. on each = 3.75 volts.

The surface of each coil is $25 \times 628 = 1670$ sq. cms and at 20 sq. cms. per Watt this gives 83.5 Watts @ 3.75 volts = 22.3 amp.

The res: of the coil must thus be $\frac{3.75}{22.3} = 0.0168 = K = \frac{(261-23)10^{-6} \times 22}{}$

so that $d = -0.02 + \sqrt{\{0.00014 + 0.00153\sqrt{\frac{2246}{0.0168}}\}}$

$0.00153\sqrt{133700}$

0.00153×365.7

0.5595

0.5599

$+ 0.7483$

$= 0.728$ cm.

$= 0.287"$ #2 B&S. 0.30" correct:

in 9" there will be 27 turns, and in 0.76" 2.5 layers = 675 turns in all and with 22 amperes 14.90 a.t. while 5000 are needed.

Mean turn = 1.8 ft 1285

If the current in the coil be kept the same but each limb to be doubled in ~~so~~ then $d = -0.02 + \sqrt{\{0.00014 + 0.00153\sqrt{6.6850}\}}$

0.00153×2.59

0.4120

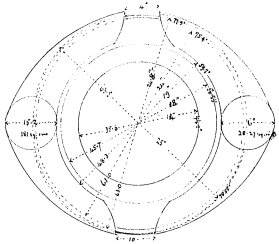
$\sqrt{0.41215}$

0.6422

$= 0.622$ cm $= 0.245"$ #4 nearest typ.

36 turns per layer × 3 layers = 108 turns. correct = 0.25"

1/8



Volume of armature $0.785\,(24^2 - 18^2) \times 0.8 \times 8 = 1267$ c.i. @ 0.35 = 443 lbs.

Breadth 8" (20·3) but: diam: on iron wire 24" (61)
but . . . . 18" (45·7)

Thickness of bars above top 0·4" (1·02)
below 2·0" (5·1)
on sides 0·4" (1·02)

Sectional area of each bar. 0·85 sq cm.

Breadth of each bar above $\frac{73.9}{200}$. 0·386" say 0·35" (0·84)

Res: of each upper bar approx $\frac{1.7 \times 35}{0.85} = 70$ microhms.

. . . under . . $\frac{1.7 \times 22}{10 \times 0.6} = 7.5$

Res: of each complete turn with joint 80 . approx
. . entire ring 4,000 .
. . . armature 1,000 . = 0·004

fall of potential with 500 amperes = 0·5 volts.

Revolutions of armature per minute 300
. . . . second 5

Peripheral speed 1950 ft: per min: = 1990 cms per sec.

Calculated total flux 4.2×10^6

Electromotive force $4.2 \times 10^6 \times 5 \times 100 = 21 \times 10^8$

There will be 200 bar every pair in multiple.

180 sq cms: in field magnets @ 15×10^6 = 2.7×10^6 lines.

Surface of polar face covering armature =

$0.8 \left\{ \frac{0.785}{4} (24^2 - 19^2) + 8(2g) \right\}$

16g + 312

481

385 sq in. = 2480 sq. cms.

The reluctance = $\frac{2 \times 1.27}{2480} = 0.00102$ but.

Allowing 3 times the reluctance as the total in est. = 0.003

The ampere turns for each pair of magnets = 10,000 = 5000 on each limb

(133)

Electrical Design for a Street Car motor of 10 kwts. power to run at 300 revolutions per minute at 500 volts & 50 amps. amperes

The diameter of the armature gramme ring happens to be 24" (61) externally and 20" (50·8) internally, and 6" (15·2) broad.

The section of this armature will then be $5.1 \times 15.2 \times 0.8 = 62$ sq cm which @ 16,000 lines = 992,000 say 1.0×10^6

$$s \times 10^6 \times w = 500 \times 10^8$$

$$w = \frac{10^{2}}{2} = 5000$$

so that 5000 wires must be in series round the whole armature and 2.0×10^6 useful lines have to be furnished.

In 4 layers this will represent 1250 wires all round.

At the diameter of 19·5" this circumference = 61·25" and allowing for fibre 60" this leaves 0·048" for each wire and with 0·018" for insulation 0·030" = #20 B.W.G. 1225 c. mils.

The resistance of the armature will be about $\frac{5000}{2} \times 1.4 \times 8.5 \times 10^{-3}$ $= 1.25 \times 1.4 \times 8.5 =$ 14·9 ω

If required to deliver 21 volts @ 500 amperes.

Let D be the ext: diam: of the wire armature cms
d - - int: - - - - - -
b - - breadth

Then the section is kb(D − d) where k is a constant less than unity) representing the ratio of iron to volume. say 0·8

The weight of iron is $0.7852\,b(D^2 - d^2)k\sigma$ where σ = sp: gr: of iron

If φ be the density of flux permissable in the armature

$$kb(D-d)\varphi = \Phi \text{ the total flux}$$

and $5\,w\Phi = 2.1 \times 10^8$ where w = number of bars

$$w\Phi = 4.2 \times 10^8$$

Let t be the thickness of the winding above
- - - res: of the armature between its plane

Then $\frac{t}{kb}\rho w$ is the resistance of each turn

$\frac{\rho w^2}{2}$ - - - the whole armature

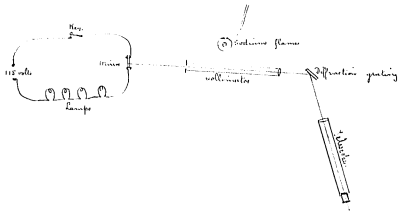
For a trial value let Φ be 4.2×10^6 bifurcating into two streams each of 2.1×10^6 requiring at a density of 17×10^6 1.24×10^6 = 124 sq. cms @ 2" depth (5·1) 24·3 cm 9·57" ÷ 0·8 = 12"
2·5" - (6·35) 19·5 " 7·68" ÷ 0·8 = 9·6"
3" - (7·62) 16·3 " 6·42" ÷ 0·8 8·"

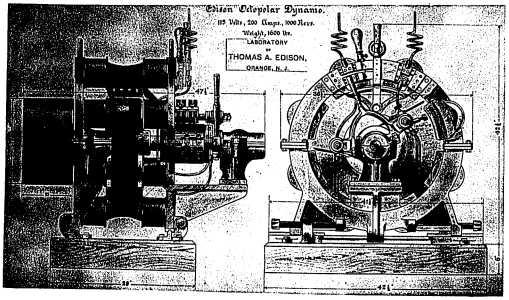
The int: diam: will be 18" and the circumference 56·5"5

With 200 bars the space allotted to each will be 0·283" and allowing for insulation 0·25".

The field magnets have to supply 4.2×10^6 usefully in say 5.5×10^6 allowing for leakage. If there are two fields Each must create 2.75×10^6. At 15000 lines per sq. cm. their area is $\frac{2.75 \times 10^6}{1.5 \times 10^4} = 1.83 \times 10^2 = 183$ sq. cms = 15·3 cms in diam.

= 6".





Experiment on Electric Current Sheet.

14. I. 90. A slip of silvered glass 5 × 3·3 and 0·69 thick was held in the a nearly vertical plane between two copper clamps on a wooden block. The reflecting film of metal offered a resistance between the clamps of 24 ω. The reflector was placed about 20 cms from the slit of the spectrometer and a Bunsen burner with a sodium flame was then placed in such a position that the reflected image of the flame fell upon the diffraction grating. The two D lines were then focussed upon the hair line of the telescope eye piece. Under these conditions, a current supplied from the 115 volt circuit through 3, 2, + 1 lamps was passed through the metal reflecting film, i.e. 0·17 0·25 + 0·5 amperes. The direction of the current was first horizontal and subsequently by placing the mirror + support on its side, vertical; but although contact was made by a key, and a very slight displacement could have been observed, no movement of the image could be observed, although at first it was imagined to do so. The object of the experiment was to ascertain whether assuming electric current to be ether flow, the passage of electricity along the surface of a conductor in any way altered the direction of a beam of light incident upon it. Thus far the result is negative.

On the conditions necessary to obtain a ballistic galvanometer with a period of three or four minutes.

The mass and suspension torsion are to be minimum. The moment of inertia, and magnetization, maximum.

$$T = 2\pi\sqrt{\frac{I}{mH}}$$

where I is the moment of inertia about the vertical, m the magnetic moment of the ballistic system and H the field. mH represents the moment of the resultant directive force on the magnetic system round the vertical. By making the system sufficiently astatic this resultant moment can be indefinitely diminished. There is however a practical limit for sufficient directive force must be left to bring the system back to zero. I must therefore be increased.

On the Magnetic circuit of the New Car motor

continued from pages 132 and 133

The reluctance of the air space is 0.00102

" " of two cores 10" long (25.4 by 181 section)

" " " $\frac{25.4}{181} \times \frac{1}{300} = \frac{25.4}{54300}$ 0.00047

" " one yoke of wrought iron 25" long (63.5 by 180 section) $= \frac{1}{200} \times \frac{63.5}{180}$

$= \frac{63.5}{54000}$ 0.00118

" " of a cast iron hood mean path $12" \times 12$ sq. in $\frac{25}{76} \times \frac{1}{200} =$ 0.00764

opposite hood 0.00764

" " armature mean path 30" long by 12.4 sq. ins × section @ 18000 . 300

$\frac{30}{12.4 \times 300} =$ 0.00808

Circuit $= 2\,(0.00084) + \frac{0.00204 + 2(0.00328)}{2} + \frac{1}{2}\,(0.00118 + 0.00047)$

$= 2\,(0.0027) + 0.00083$

$= 0.0052 + 0.00083$

$= 0.0062$ lines.

Entrefer	0.00102
Armature	0.00184
Hoods	0.00328
Bows	0.00059
Yokes	0.00047
	0.00617

If the hoods be made of sufficient section the total reluctance will fall to 0.003, and the magnetomotive force for 18 volts $= 3.6 \times 10^4$, and allowing 25% for leakage $= 4.5 \times 10^4$.

$4.5 \times 10^4 \times 3.0 \times 10^{-3} = 13.5 \times 10^3 = \frac{13500}{1.287} = 10740$ AT per pair

5370 AT per limb.

On the conductors required to carry 100 amperes from the Phonograph Works Engine Room to the New Toy Building a distance of 350 feet at 7 volts fall.

Res $= 0.07\,\omega \div 700 = 0.01 \div 100 = 0.0001\,\omega$ per foot.

= equivalent to a # 1 wire, or 6 # 10 wire. approximately.

$= 700 \times 6 = 4200$ ft. of # 10 wire $= 4.2 \times 10^3 \times 5.44 \times 10^{-2} = 22856 \times 10$

= 220 lbs. of # 10 wire (stranded say) 230.

1 c.c. of 98% copper has a res. of 1.778×10^{-6} ω @ 20°C.
1 foot " " " " 1 grm. " " " 5.19×10^{-6} ω " "
1 " " " " 1 sq. in. " " " 8.02×10^{-6} ω " "
1 " " " " 1 sq. mil " " " 8.02×10^{-12} ω " "
1 " " " " 1 mil " " " 10.70 ω

pure copper has a resistivity of 1.624×10^{-6} ω @ 0°C.
1.750 " @ 20°C.
99.7 " 1.767 " " or 1 mil foot .. 10.635
98 " 1.785 "

$$D^2 = 0.7854\, l\,(C^2 - c^2)\sqrt{\frac{\rho\sigma}{m\tau}} \qquad \sigma = 8.95$$

$$d^2 = 1.2732\sqrt{\frac{m\rho}{\tau\sigma}}$$

$$m_{gm} = (0.7854)^2\,\frac{\tau\sigma}{\rho}\,d^4$$

For 98% copper @ 8°C
or 100% " " @ 10°C.

$$= 0.6168\,\tau \times \frac{8.95}{1.7\times10^{-6}}\,d^4$$

$$= 3.24\,8 \times 10^6\,\tau \times d^4 \quad (1.7\times10^{-6})$$

$$= 3.063 \times 10^6\,\tau \times d^4 \quad (1.8\times10^{-6})$$

$$m(\text{lbs}) = \frac{2.979 \times 10^{-7}\,\tau\,d^4\,(\text{mils})}{2.807 \times 10^{-7} \text{ for } 1.8\times10^{-6}}$$

A wire offering 1 ω res (τ = 1) and of diam 0.1

$$m = 3.248 = 0.736 \text{ lb.}$$

$$d_{inc} = \frac{0.02326}{0.0237} \sqrt[4]{\frac{m}{\tau}}\,\tau_{inc} \quad \text{or} \quad \text{for } 1.8\times10^{-6}$$

$$d_{mil} = \frac{4.292}{4.3145 \times 10} \times 10^4 \sqrt[4]{\frac{m\,\text{lb}}{\tau_{inc}}}$$

$$\tau_{inc} = 3.1645 \times 10^{-7} \cdot \frac{m}{d^4}\,\tau_{inc}$$
$$= 3.079$$
$$3.266 \quad (1.8\times10^{-6})$$

$$\tau_{inc} = \frac{3.779 \times 10^6}{3.357}\,\frac{m\,\text{lb}}{d^4_{mil}} \quad \text{for } 1.8\times10^{-6}$$

In the wire tables for wire at higher temperatures.
These are

$$m_{lbs} = 2.9327 \times 10^{-7}\,\tau_{inc}\,d^4_{mil}$$

$$d_{mil} = 4.3014 \times 10 \sqrt[4]{\frac{m\,\text{lb}}{\tau_{inc}}}$$

$$\tau_{inc} = 3.1494 \times 10^6\,\frac{m\,\text{lb}}{d^4_{mil}}$$

General Formulae for the Winding of Magnets.

Let τ be the number of ampere-turns required on the spool
m - - weight of copper allowed in grms.
c - - diameter of the core cms
C - - - - - core after winding cms.
d - - - - - wire cms.
D - - - - - wire covered cms
t - - thickness of covering $\left(\frac{D-d}{2}\right)$ cms
l - - length of the core between flanges.
σ - - sp. gr. of copper 8.95
ρ - - resistivity of copper 1.7 microhms.
β - - limiting number of watts per sq. cms. of surface per watt.
λ - - length of wire on the spool cms.
r - - resistance - - - hot. ω.
ε - - p.d. on the spool - - - volts.

Then the winding space $= 0.7854\, l\,(C^2 - c^2)$
of this volume $0.7854\, d^2$ is occupied by copper
so the volume of copper is $\frac{(0.7854)^2\, l\, d^2\,(C^2-c^2)}{D^2}$

. . weight . . $m = \frac{(0.7854)^2\, l\,\sigma\, d^2\,(C^2-c^2)}{D^2} = \frac{\beta d^2}{D^2}$

. . length . wire $\lambda = \frac{0.7854\, l\,(C^2-c^2)}{D^2}$

. . number of turns per layer $= \frac{l}{D}$

. . - - - layers $= \frac{C-c}{2D}$

. . total - - turns $= \frac{l\,(C-c)}{2D^2}$

. . length of the mean turn $= \pi\left(\frac{C+c}{2}\right)$

. . res: of the spool $r = \frac{\lambda\rho}{0.7854\, d^2}$ ohms

$= \frac{l\rho\,(C^2-c^2)}{D^2 d^2}$ ohms

. . current in the spool $= \frac{e\, D^2 d^2}{l\rho\,(C^2-c^2)}$ amperes

. . (heat) energy) - - - $= \frac{e^2 D^2 d^2}{l\rho\,(C^2-c^2)}$ watts

. . energy per unit surface $h_f = \frac{e^2 D^2 d^2}{\pi C l^2 \rho\,(C^2-c^2)}$ watts per sq. cm.

. . ampere turns $\tau = \frac{l\,(C-c)}{2D^2} \times \frac{e\, D^2 d^2}{l\rho\,(C^2-c^2)}$

$= \frac{e\, d^2}{2\rho\,(C+c)}$

In every practical problem c is given while e is susceptible of little variation. ρ, σ, β, β, are known. a and m are fixed limits that must be complied with by the use of suitable values of d and l.

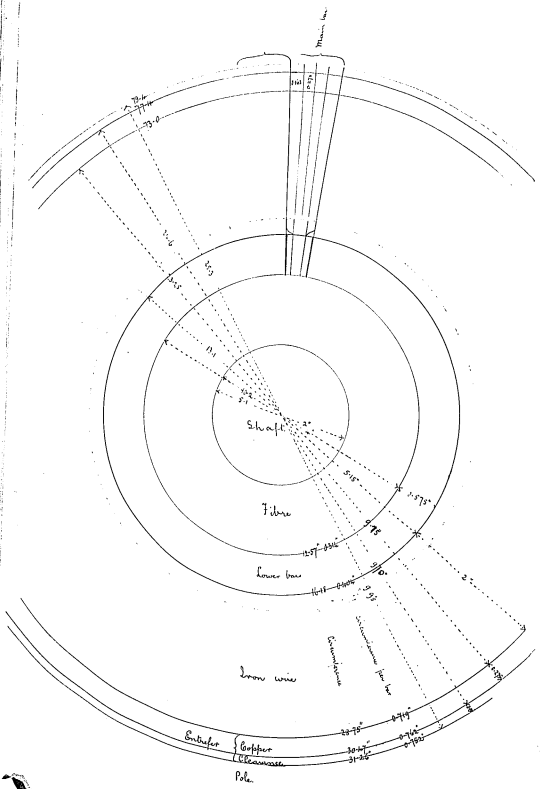
The final equations are

$$d = \sqrt{\frac{2\rho\tau\,(C+c)}{e}} \qquad d^2 = \frac{2\rho\tau\,(C+c)}{e}$$

(1) or $d = 0.002\sqrt{\frac{\tau}{e}(C+c)}$ $\qquad d^2(\beta - m) = 2mlt + mt^2$

(2) $m > \beta\left(\frac{d}{D}\right)^2$ $\qquad d^4(d+t)^4 < \frac{l\sqrt{h\pi\sigma\rho\,(C^2-c^2)}}{c}$

(3) $l > \frac{c\, d^2}{\sqrt{h\pi\sigma\rho\,(C^2-c^2)}}$



Modification of the Street Car Motor

Sprague model to suit 20 volts.

The # 6 500 volt model at present in use has 62 dis: in its armature and 12 wires in each = 744 wires all round. Its speed is from 1025 to 1060 revs per min: mean 1050 or at abt 17.5 revs: per second. $\therefore\ 17.5 \times 744 \times \phi = 500 \times 10^8$

$$\phi = \frac{5.0 \times 10^{11}}{1.75 \times 0.744 \times 10^{10}} = \frac{5.0}{1.30} \times 10^1 = 3.84 \times 10^8$$

Assuming the same speed to be retained in a bar armature of the gramme ring type with 20 volts.

$$\frac{744 \times 18}{500} = 14.88 \times 18 = 267.84$$

$$17.5 \times 267 \cdot 3.84 \times 10^8 \times n = 18 \times 10^8$$

$$n = \frac{18 \times 10^8}{1.75 \times 3.84 \times 10^7} = \frac{18}{6.72} \times 10 = 26.8$$

say 30 bars with a little weaker field.

The diam: of the armature over a bound is $9\frac{7}{16}" = 9.7"$

" " " now cor will be about 9".

" area of iron will be about 9" × 10" × 6.48 × 0.8 = 464 sq. cms.

If the thickness of the ring be 2" the section will be . 208 " .

The flux being $3.84 \times 10^8 \div 2.08 \times 10^2 = 1.92 \times 10^6 = 19.200$ lines per sq.

This must be brought down to about 15.000 making $\frac{26.8 \times 19.2}{15} = 34.3$ bars

As a first approximation 40 bars may be used.

The circumference of the armature $\frac{9.7 \times 3.14}{40} = 30.458" \div 40 = 0.762"$

If 0.162 bar be used 0.648" will be occupied by them at the surface leaving 0.114" for four thicknesses of insulation = 0.029" each.

The area of the upper annular bar space is $0.7854(9.7^2 - 9.15^2)$

$0.7854(94.09 - 83.72)$

$0.7854 \times 10.37 = 8.146$ sq. in.

The area of the lower bar space is $0.7854(5.15^2 - x^2)$

$\therefore\ -0.7854x^2 = 8.146 - 2.7854(26.52)$

$x^2 = -10.37 + 26.52 = 16.15$

$x = 4.019$ say 4.0

Lower bars have an upper breadth of 0.575" full allowing ⅛ nearest size is 9/16" = .056 The breadth is 0.404" theoretical + allowing 0.029" for insulation leaves 0.375" for the upper breadth ⅜". 40 of these bars 12" long will be needed = 40 feet of bar. The upper bars will be 160 in number 0.162" in breadth and 0.275" deep.

Description of the 10 kilowatt 1000 volt – 20 volt Transformer as completed from electrical designs recorded in the earlier part of this book.

For the general dimensions reference may be made to the Dynamo this print book where they are entered in due form. The section of the armature is correctly given on page 85 except that 12 instead of 14 large wires are braided upon each of the outer 2 layers. That is to say owing to the braiding only 24 wires could be inserted instead of 28 as originally designed. The diam: of the armature over the brass wire bands is rather less than 7.5". The armature body is as standard #14, but with the slots increased to 96 at each end. Winding 1 # 17 B.S. 0.0453 sq.g brass wire
12 # 11 B.S. 0.091 sq over wire

The bore of the fields is 7.85" allowing 0.15" clearance.
The fields are regular F.I.C. with the #4 keeper, & zinc.
The bed plate is specially cast.
The winding of the fields is 60 lbs. of # 11 B.W.G. on each limb 120 lbs in all = 1.0 cwt. approx, and when joined up in multiple are = 0.5Ω.
The series winding is in a separate coil at the base of each limb of which height it occupies about 0.75; It consists of 96 turns see p. 104 of # 14 B.W.G 0.093" 48 turns on each limb 4 layers high, 12 around.

Test of a small miner's lamp battery at Mr Hastings request

This battery consists of 4 cells contained in a wooden box 15.2 high × 10 × 10. It weighs 4 lbs 8 oz. alone when charged, and with its lamp and cover attached 4 lbs 14 oz. The resistance of the lamp is 14.4 hot, 2½ cp. The p.d. on the lamp was 5.6 volts and the current 0.4 ampere. The lamp was then replaced by 14.4 of platinoid res:, and observations taken Jan: 16th

No. of obs	Jan 16th time	Time from start	EMF volts	P.D. volts	C. amps	C²	r ω	Batt. Eng. Watts	Ext. Eng. Watts			
1	10.0	0	7.0	5.75	0.41	0.17	3.0	2.38	0.51			
2	11.0	1.0	6.95	5.7	0.40	0.16	3.0	2.24	0.48			
3	12.0	2.0	6.91	5.68	0.40	0.16	3.0	2.24	0.48			
4	13.0	3.0	6.73	5.24	0.37	0.14	4.0	1.96	0.56			
5	13.30	3½	6.3	4.96	0.35	0.12	3.83	1.68	0.46			
6	14.0	4.	5.94	3.11	0.22	0.05	12.0	0.7	0.60			
7	14.30	4½	4.02	2.00	0.14	0.02	14	0.28	0.28			

The output of the cells is thus (practically) 1.5 amp. hrs. Second test after recharging) cell with Solution of $6\,H_2O$ & H_2SO_4 + KNO_3

No. of obs	Jan 18th Time	Time from start	EMF volt	P.D. volt	C. amp:	C²	r ω	Batt. Energy Watts	Ext. Energy Watts			
1	9.0	0	7.1	5.62	0.40	0.16	3.7	2.24	0.59			
2	.10	.	6.82	5.3	0.38	0.15	3.8	2.1	0.57			
3	.30	½	6.68	5.2	0.37	0.14	4.0	1.96	0.56			
4	10.0	1.0	6.28	4.9	0.35	0.12	4.0	1.68	0.48			
5	.30	1½	6.18	4.34	0.31	0.096	6.0	1.34	0.58			
6	11.0	2	5.62	2.98	0.21	0.044	10.0	0.62	0.44			
7	11.30	2½	4.80	2.48	0.18a	0.032	10.0	0.45	0.32.			
	a third trial gave even worse results											

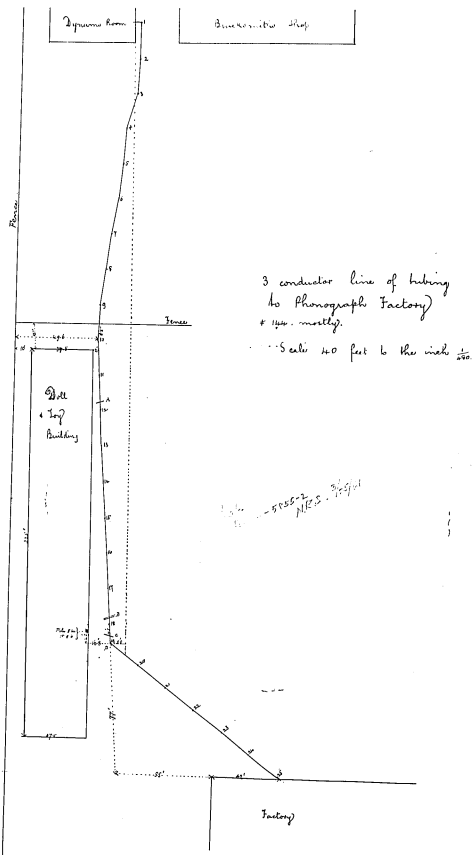


Diagram shewing the position and course of the line of electric pipe conductors from the Laboratory to the Phonograph Works as altered Jan. 90.

The tubes were taken up between boxes #s 10 and 29, and relaid as shewn. A short length (11.5') is inserted between 18 & 19. The position of the corner D (box # 19) is shewn with reference to the laboratory line, an offset from the long building, and a pair of lines with the factory.

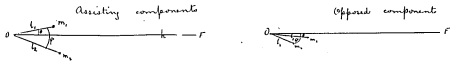
Pipes cross above the tube at A B & C.

A is a 3" water pipe, 1 foot above. & distant 4.5' from 12, mm

B . . 12" rectangular drain from the pond 1.5' feet above & 14.7' from 19

C . . 3" water pipe 6" above, & distant 4.5' feet from 19.

On the conditions of equilibrium direction in an astatic suspended system.



Let O be the center of the astatic system

$m_1 l_1$ be the moment of one component

$m_2 l_2$ . . . . the other.

φ . . angle between the two

θ . . . of equilibrium.

Then $l_1 m_1 h \sin\theta - l_2 m_2 h \sin(\theta + \varphi) = 0$

$$\therefore \frac{\sin(\theta+\varphi)}{\sin\theta} = \frac{l_1 m_1}{l_2 m_2} = n \text{ say.}$$

$$\sin\theta\cos\varphi + \cos\theta\sin\varphi = n\sin\theta$$

$$\sin\theta(\cos\varphi - n) = -\cos\theta\sin\varphi$$

$$\sin^2\theta(\cos^2\varphi - 2n\cos\varphi + n^2) = (1-\sin^2\theta)\sin^2\varphi$$

$$\sin^2\theta(1 - 2n\cos\varphi + n^2) = \sin^2\varphi$$

$$\sin\theta = \frac{\sin\varphi}{\sqrt{1-2n\cos\varphi+n^2}}$$

When $n = \infty$ $\theta = 0$

$n = 0$ $\theta = -\varphi$

$n = 1$ $\sin\varphi = \sin\varphi / 2\sqrt{1-\cos\varphi} = \sin\varphi / 2\sin\frac{\varphi}{2}$

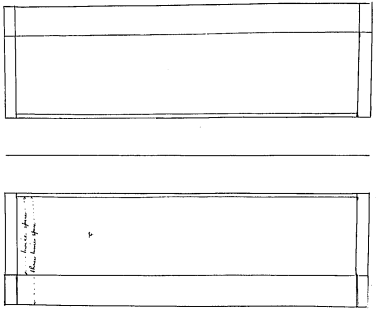
$$= \frac{2\sin\frac{\varphi}{2}\cos\frac{\varphi}{2}}{2\sin\frac{\varphi}{2}} = \cos\frac{\varphi}{2}$$

In this case if $\varphi = \frac{\pi}{2}$ $\theta = \frac{\pi}{4}$

If $\varphi < \frac{\pi}{2}$ $\theta > \frac{\pi}{4}$

Analysis of the Edison Dynamo Magnetic Efficiency.

Number of Spires	Speed Revolutions per min.	Power	Power expended all work	Field Flux Φ $\times 10^{-6}$	E volts	Field Flux Φ $\times 10^{-6}$	E volts	X Section Field Flux Φ sq. cm.	Field Flux Φ lines per sq. cm.	X Section Field Magnet Φ sq. cm.	Field Flux Φ lines per sq. cm.	X Section Field Magnet Φ sq. cm.	Field Flux Φ lines per sq. cm.	Outer Diameter	Inner Diameter
1	1900	31·67	528	0·7676	125	0·757	131·6	127	6·2000	127	6·2000				



For test of this coil on completion see table on page 101.

On the winding of a still more powerful Phonoplex Induction coil intended for special work.

On page 93 is given the winding of a coil whose test is shewn on 101 with theoretical considerations on page 103. The effect of using this coil increasing the time constant from 0.018 to 0.022 seconds ratio (2.33) was to increase the practical working distance from 175 miles to 250 approximately (1.4) so that judging from this experiment the limiting distance varies as the square root, or even less rapidly than the square root of the coil power.

The time constant of a coil without iron we know to be independent of its length, but if the coil is too short some effect must be lost when an iron core is used. We may therefore take the last coil of page 93, add 25% to its length, keep the resistance the same, and double the annular coiling space, while doubling the cross section of core.

It is not yet known whether the power of different coil having the same time constant and general dimensions is practically independent of their resistance.

L was	10.6	and will now be	13.3	=	~~5.24~~"
l -	1.9	" " "	12.4	=	4.88"
r -	1.9	" " - -	2.687	=	10.6"
y -	2.15	- - - - -	2.94	=	1.16"
x -	6.15	- - - - -	~~18.84~~ 8.66	=	3.41"

$$d = -0.007 + \sqrt{\left(0.00153\sqrt{\frac{646.5}{5}}\right)} \Big/ \sqrt{129.3}$$
$$+ \sqrt{0.00153 \times 11.37}$$
$$+ \sqrt{0.01714}$$
$$+ 0.132$$

$= 0.125$ mm

$= 0.049"$ = #18 silk covered wire

The mean diameter is 2.24" = 7.04" circumference = 0.59'
The diam: covered = 0.052". There will thus be 90 turns to the layer + 1.13" dep. = 20 layer = 1890 turns = 1115 ft = $4.3 \times 10^{-3} \times 1.115 \times 10^3 = 4.80$ ω.

Trial of a Transformer previous to placing it in its box underground.

22nd Jany. 90.

Speed 1320 revolutions per minute.
Pressure at primary terminals 1060 volts Current 1.7 ampere
- - secondary - 20.0 - - 40 - through fields.
Watts absorbed 1800 Watts utilized 800 in fields.
- lost in primary armature 15.
- absorbed in (rotating) armature through fields 980.

Transformer # 1 ran from 10 to 18 o'clock almost uninterruptedly. At 18 o'clock, the temperature of the cores and framework was 130° F (55°C). That on the armature 135°F (57°C)

Let r be the rad. of the ring
θ be its inclination to H.
Then the lines included will be $\pi r^2 H \sin\theta$
and if this ring be revolved, the emf e generated is

$$e = \frac{d(\pi r^2 H \sin\theta)}{dt} = \pi r^2 H \cos\theta \frac{d\theta}{dt}.$$

Let the no. of revs. per sec = p Then $\frac{d\theta}{dt} = 2\pi p$.
and $e = 2\pi^2 r^2 H \cos\theta\, p$.
If there be n turns and the mean radius is R

$$e = 2n\pi^2 R^2 H \cos\theta\, p$$

or if the total area $A = n\pi R^2$ be inserted

$$e = 2\pi A H \cos\theta\, p$$

and the maximum e.m.f. E

$$E = 2\pi p A H$$

or if the total induction AH at maximum be Φ

$$E = 2\pi p \Phi$$

2.

Telephonic Experiment with revolving coil

(1142)

22nd January 90.

A ring about 15 in diam. was roughly mounted in wooden horizontal bearings. It was caused to rotate about a horizontal diameter by pulleys & multiplying gear. On the ring was wound five platinoid wires in two coils of 100 turns each. One turn of the driving wheel made about 21 turns of the coil. When driving at 40 revolutions per minute with the earths vertical field assumed at 0.2 the e.m.f developed, at the maximum by the coil, whose terminals were connected to collector rings & strips would be in each 100 turn section

$$\frac{40}{60} \times 2\pi \times 21 \times 0.7854 \times 225 \times 100 \times 0.2 \times 10^{-8} \text{ volt}$$

$$0.667 \times 2\pi \times 2.1 \times 0.7854 \times 2.25 \times 1.0 \times 2 \times 10^{-4} \quad "$$

$$9.918 \times 10^{-4} \text{ volt} = 0.00299 \quad "$$

With both coils in series $\quad 0.006$ "

No sound was heard in the telephone when the latter was directly connected with the rotating coil but when a vibrating armature was in the circuit as a rapid make and break the sound produced by rotating the armature was quite distinct.

Sewing Machine Tests with Low Tension Dynamo.

23rd Jany. 90. With the phonograph motor revound as described on page 127. The following results were obtained.

P.D. of 6 volts at his bars. Res. of field 3.4 ω armature 0.33 ω

No. of lbs.	Revs. per min.	Current	P.D. at terminals	Revs. of Sewing Machine	Watts absorbed	Current in field	Watts in field	Current in armature	Watts in armature	Back emf in armature	Emf. developed in armature	?
1	400	7.5	5.1	800	38.3	1.5	7.65	6.0	12.0	2.0	2.1	4.60
2	0	14.8	4.3	400	63.6	1.26	5.38	13.5	58.	4.3	"	
3												
4												

at this speed and power the work done by the machine was very satisfactory, it sewed through 4 ply muslin without any great difficulty.

Required the number of K40 cells to produce the same results.

Let n be the number with 0.05 ω int. res. and 0.7 emf volts

Then $0.7n - 7.5 \times 0.05n = 5.1$

$0.7n - 0.375n = 5.1$

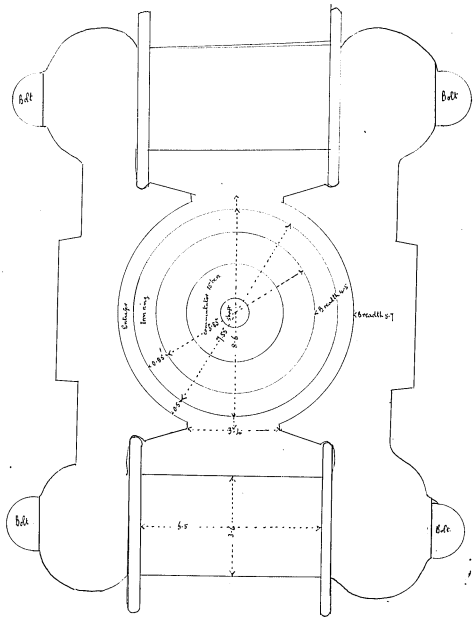
$0.325n = 5.1$

$n = 16$ cells approximately.

of which 7.3 are required to make up the p.d. at terminals

No. of cells	e.m.f each	Total emf.	res. of each	Total res	current amp.	field in battery	p.d. at terminals with	Watts in circuit	Watts lost in battery	Lost in motor field	Watts usefully employed	?
16	0.7	11.2	0.05	0.8	7.5	6	5.2	39	45	7.7	31	26
10	0.7	7.0	0.025	0.25	7.5	1.88	5.1	52.5	14.8	7.7	31	24

Full size. Cast iron.



Armature winding

Gramme ring 15 sections

Each section 11 wire bond 3 high # 22 BWG D.C.C. 0.028"

495 wire all round = 210 ft = 54' equivalent to 0.71 w. ½ lb.

Field winding

14 oz. on each limb of # 23 BWG. 0.025" D.C.C.

1 lb. 12 oz. in all.

Speed 2400 revs. per min = 1900' per min at periphery.

On the best winding for a pump motor of dimensions shewn to be operated by a 440 battery.

The work actually required to be done is stated at 125 gallons of water 50 feet high per hour. $3.786 \times 10^3 \times 1.25 \times 10^3 \times 4.5 \times 10^2 \times 3.05 \times 10^1$

$= 3.786 \times 1.25 \times 4.5 \times 3.05 \times 10^7$ ergs per sec. $= 6.5 \times 10^8$ ergs per sec.

$= 6.5 \times 44191 \times 10^{10}$ Foot lbs $= 6.37 \times 10^{14}$ per hour $\div 3.6 \times 10^3 = 1.77 \times 10^{11}$

$= 17.7$ Watts.

In the absence of definite information we may assume the efficiency of the pump to be 0.5 so that 35.4 Watts will be needed from the motor. The motor itself may be allowed to have a gross efficiency of 0.50 thus demanding a development of 70.8 Watts by the battery, suppose 75.

If 15 volt + 5 amperes be adopted we require 21 cells @ 0.7 volts and with each cell 0.05 ω. the res: = 1.05 ω. It is therefore required to wind the motor for 1 ω res:

The radial winding space is $0.7854\,(8.4^2 - 7.55^2) = 10.65$ sq. cms. the total is $4.5 + 0.85 = 5.3$ so that the actual space above the ring allotted to winding = 56.5 c.c. Allowing as much for the interior space = 113 c.c., and reducing for insulating division leaves about 100 c.c. ρ may be $24.00\,(\frac{2}{3})^2$ microhms. The length of the mean turn $= \frac{2}{3}\,(4.5 + 0.85 + 5.4 + 1.65) = 12.4$

Then $t = \dfrac{w^2 l^2 \rho}{2h}$ $\therefore 1 = \dfrac{w^2 \times 10^{-4}\,l^2 \times 2.4 \times 10^{-6} \times 1.46}{2.00 \times 10^{-2}}$

$200 = \dfrac{10^2 \times 1.54 \times 2.4 \times 2.0 \times 10^{-4}}{} = w^2 \times 3.70 \times 10^{-4}$

$w^2 = 10^6 \cdot 3.70 = 270.00$ $w = 520$ say 525

The length of wire is thus 525 × 0.141' = 24 ft = 56' per ~~[illegible]~~ BWG 0.028 covered = 0.0882.

The surface circumference = 7.85 × 3.142 = 24.7 = 7.24". allowing for insulation = 6.5 ÷ 0.028 = 195 wire + 3 deep = 585 wire = 33 wire to each division or 3 layer of 11 × 15 (165) early. = 495 wire.

At 2400 revs. per min = 40 per sec.

$40 \times 500 \times \phi = 7.5 \times 10^8$

$\phi = 7.5 \times 10^1 \div 2 \times 10^4 = 3.75 \times 10^4$

$= 37.500$

ϕ in the armature is $\frac{18750}{2.52} = 4.900$.

The reluctance of the air space is $0.5 \div 2.52 - 6.5 = 0.5 \div 19.4 \times 4.5$

$= 0.5 \div 82.8 = 1 \div 165.6 = 0.0060$ lines, and the mmf required to drive 50.000 lines through this = 300 on each limb.

= 238 AT on each @ 0.25 amp = 952 turns. The p.d. being 7 volts the res. must be 30 ω.

The winding space is $0.785\,(6.3^2 - 3.6^2) \times 6.5 =$

$0.785 \times 26.73 \times 6.5 = 136.4$ c.c.

$$d = -0.02 + \sqrt{0.00004 + 0.00153\sqrt{\frac{136.4}{30}}}$$

$\sqrt{4.547}$

2.13

$+ 0.00326$

$+ \sqrt{0.00366}$

$+ 0.06$

$= 0.0400 = 0.016"$ # 27 BWG. If however as this is found wire the field be in series = 7.50 each.

$d = -0.02 + \sqrt{0.00692}$

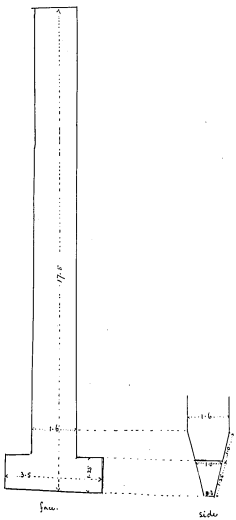
$= -0.02 + 0.083$

$= +0.063 = 0.025"$ = # 23 BWG 0.035" cont.

= 70 turns per layer @ 0.5' per turn. 14 layer = 980 turns = 490'

= 8 ω. 7.5 ω of # 23 @ 0.114' = 0.86 lbs on each limb = 1.72 lbs in all

Solid copper



Coefficient of Expansion of Wax Cylinder or Ring in Phonographic Doll.

23rd Jany. 90. From the means of seven observations, the ring has a diameter of 2·729" @ 66°F

+ 2·717" @ 39°F

0·012" for 27°F = 15°C.

0·0008" " 1°C.

coeff: 0·000298 linear expansion 1°C. between 4°C + 19°C.

On the best winding for an electrically heated copper soldering iron of given dimensions

The surface intended to be exposed is that of the widened part it is $2\{(3{\cdot}5 \times 1{\cdot}25) + (3{\cdot}5 \times 0{\cdot}15) + (0{\cdot}65 \times 1{\cdot}2)\}$

$2\{3{\cdot}5 \times 1{\cdot}4 + 0{\cdot}65 \times 1{\cdot}2\}$

$2(4{\cdot}9 + 0{\cdot}78)$

$2(5{\cdot}68) = 11{\cdot}36$ sq. cms.

The radiation in Watts per sq. cm. from this surface blackened will be $2 \times 0{\cdot}0687\,(1{\cdot}0077^{273} - 1)$

$\log 1{\cdot}0077 = 0{\cdot}0033303$

$\times 273$

$0{\cdot}909090$

$1{\cdot}6667$

$46{\cdot}3$

$2 \times 0{\cdot}0687 \times 46{\cdot}3$

$6{\cdot}23$ Watts.

and for the entire surface 70·7 Watts.

Allowing as great a loss for working purposes + for conduction leakage we have to supply 120 Watts. = 1·2 amperes. from 110 volts = 84·5 ω hot resistance of iron wire.

Siemens gives for iron $r = 0{\cdot}0725445\sqrt{T} + 0{\cdot}0038133\,T - 1{\cdot}2397$

for 20°C $T = 293$ $\quad r_{20} = 0{\cdot}0725445 \times 17{\cdot}1 + 0{\cdot}0038133 \times 293 - 1{\cdot}2397$

600°C $T = 873$ $\quad r_{600} = 0{\cdot}0725445 \times 29{\cdot}5 + 0{\cdot}0038133 \times 873 - 1{\cdot}2397$

$r_{20} = 1{\cdot}2241 + 1{\cdot}12 - 1{\cdot}24$

$r_{600} = 2{\cdot}14 + 3{\cdot}33 - 1{\cdot}24$

$r_{20} = 1{\cdot}12$ $\quad \frac{r_{600}}{r_{20}} = 3{\cdot}44$

$r_{600} = 4{\cdot}23$

The resistance at 20°C required is thus 24·6 ω.

One turn of wire round the copper cylinder over insulation will be about 5·7 cms long. Suppose 100 turns of wire = 570 cms. Then

$\frac{570}{5} / = 24{\cdot}6$ $\quad \therefore / \frac{570 \times 0{\cdot}785}{d^2}(10{\cdot}0) \times 10^{-6} = 24{\cdot}6$

$d^2 = \frac{570 \times 7{\cdot}85 \times 10^{-6}}{24{\cdot}6} = 182 \times 10^{-6} = 1{\cdot}82 \times 10^{-4}$

$d = 1{\cdot}35 \times 10^{-2} = 0{\cdot}0135$ cm.

$= 0{\cdot}0054''$

Experiment on the variation of electrical conductivity of iron under magnetic stress.

Jan. 24th 90. Took a glass tube 10·6 long, and $\left\{\begin{matrix}1.18 \\ 1.0\end{matrix}\right.$ external / internal diameter filled this tube as full as possible with soft iron wire 0·0105" diam (0·026) covered each 0·016" (0·041). The wire was prepared by winding from a spool round two brass pins 10·5 apart, 150 times, thus making 300 lengths of wire in the tube. The resistance of all this wire in one length was about 100 ω. The bight projected about 0·25 from each end of the tube. Insulated copper wire was then tightly wound in 89 turns round the center of the tube. The arrangement was supported horizontally between the poles of the large electromagnet. The effect of exciting the latter with 20 amperes was only to increase the resistance from 98·3 to 98·4 ω. 0·1 %. The deflection from the copper wire tube on the ballistic galv. with 6000 ω in cct. was 75 divs. while 1 co. gave 123 divs: through 0·4014 ϕ. ∴ 1 div represents 4.73×10^{-10} ϕs.

$$75 \text{ " } = \text{ " } \quad 3.55 \times 10^{-8}$$

$$\text{as: in cct. } 11,250 \times 10^{3} = 1.125 \times 10^{13}$$

$$\therefore a = 3.55 \times 10^{-8} \times 1.125 \times 10^{13}$$

$$= 3.99 \times 10^{5}$$

$$\phi = \frac{3.99}{0.89} \times 10^{3} = 4.5 \times 10^{3}$$

$$b = 5700$$

Jan. 25th On the supposition that there might be some leakage between the iron wire through cotton chaffs by abrasion in forcing through glass tube, boiled it in paraffine, cool and then repeated test as follows. Exchanged pole pieces for those ending in conical points which were brought to bear upon the extremities of the tube leaving about 0·25 clearance in all. The resistance with magnet unexcited T.B. 20·6°C 98·420 lead 1·99.

excited from 115 m		98·58 =
unexcited		98·42
Diff.		0·16 = 9643 = 0·8%

On increasing battery power to obtain more accurate reading, the resistance of the coil again became unsteady.

Ballistic throws from external tube on tube

with 7000 ω in cct. res.	12,250 =	·67	8205 000
5000 ω " " "	10,250	87	892 000
" " "	5250	177	929 000
			2641,800
		Mean	880,600

1 b.b 0·4014 ϕ gave mean 131·5 divs

$$\therefore 1.43 \times 10^{8} \times 0.4014 \times 10^{-10} \text{ abs: ϕs represent } 131.5 \text{ divs}$$

$$\therefore 1 \text{ div represents } 4.39 \times 10^{-10} \text{ abs: ϕs.}$$

$$\therefore \phi = 4.39 \times 10^{-10} \times 8.81 \times 10^{14} = \frac{38.7 \times 10^{4}}{89} = 4.35 \times 10^{3}$$

Assuming no flux through glass cotton & airspaces each of the 300 wires carried 1.29×10^{8} lines & the area of each wire = 5.59×10^{-4} sq. cms. ∴ $b = 14.5 \div 5.59 \times 10^{-4} = 259 \times 10^{4} = 25900$

This is the maximum value and the min: value is 5540 per sq. cm

Second approximation

$$D = \left(\frac{1.943 \times 2.3 \times 240}{1.5}\right)^{\frac{1}{2}} \times 10^{-2}$$

$$= (713)^{\frac{1}{2}} \times 10^{-2}$$

$$= 5.17 \times 10^{-2} = 2.035'' \times 10^{-2}$$

$$= 0.020'' \text{ correct} = 0.015'' \text{ uncorrected say } \# 28 \; 0.016''$$

$b = 1'' \div 0.020 = 50$ turns

$\frac{C-c}{2} = 1.5 = 0.6'' = 30$ layers $= 1500$ turns

Mean turn $\frac{\pi\, 16.5'}{30.5} = 1.7' \times 1500 = 2550'$ @ $0.05\frac{1}{2}$ per ft $= 135$ yds

140 yds of #25 B&S (@ 7.43×10^{-3} $= \frac{1558}{1000} \times 10^{-2} = 1.58$ lbs. 1 lbs. 9 oz.

At 30 revs. per sec: The area of the coil $= 1500 \times 3.14 \times 260$

and the emf. $e = 1.5 \times 3.14 \times 2.6 \times 2.0 \times 6.0 \times 10^{-2}$ volts

$= 1.47$ volts.

If the driving handle make 1 turns per second the multiplication must be 40 times, say $(6\frac{1}{2})^2$

From diameter 21' to diam 3"

and again from diam. 10.5" to diam 1.5".

Calculation of the best winding for the Revolving Earth Inductor.

Let the diam: of the first layer or base of ring channel be B. in this case we will assume B to be 15. The area of the winding space cross section $= a$ and B the ext: diam: over wire. Then the breadth of channel being b and ending space c we have

$$K = \frac{b}{4}\pi (B^2 - B^2)$$

$$a = \frac{b}{2}(B - B)$$

The number of turns $w = \frac{K}{\pi D^2}$ where $\tau = \frac{\pi}{2}(B + B)$

$$= \frac{2K}{\pi D^2 (B + B)}$$

The resistance $r = \frac{K\rho_1}{D^4}$

If φ be the resistance of the phone, the emf. generated by the coil making n revolutions per sec:

$$e = H \times \pi\left(\frac{B+B}{2}\right)^2 \times 2n \times w \times 10^{-8}$$

$$= \frac{H \pi n (B+B)^2 K}{\pi D^2 (B+B)} \times 10^{-8}$$

$$= H n \frac{(B+B)}{D^2} K \; 10^{-8} \text{ volts.}$$

The current maximum in the telephone neglecting the effect of inductance is

$$C = \frac{K H n \left(\frac{B+B}{D^2}\right) 10^{-8}}{\frac{K\rho_1}{D^4} + \varphi}$$

$$= \frac{\frac{h}{D^2}}{\frac{l}{D^4} + \varphi} = \frac{h}{D^2} \frac{D^4}{l + \varphi D^4}$$

$$= \frac{h D^2}{l + \varphi D^4} \quad \text{where } h = \frac{K H n (C+c) 10^{-8}}{K\rho_1}$$

$$\frac{dc}{dD} = \frac{2hD(l + \varphi D^4) - 4\varphi D^5 h}{(l + \varphi D^4)^2}$$

$$= \frac{2hD}{l + \varphi D^4} - \frac{4\varphi h D^5}{(l + \varphi D^4)^2}$$

for $\frac{dc}{dD} = 0$ $\quad 2hD(l + \varphi D^4) = 4\varphi h D^5$

$$\therefore h(l + \varphi D^4) = 2\varphi D^4$$

$$D^4(\varphi h - 2\varphi) = -hl$$

$$D^4 = \frac{hl}{\varphi \cancel{(2-h)}}$$

$$D = \sqrt[4]{\frac{l}{\varphi}} \sqrt[4]{\frac{K\rho_1 H n (C+c) 10^{-8}}{K[2 - \varphi H n (C+c) 10^{-8}]}}$$

$$\frac{K\rho_1}{D^4} = \frac{\varphi\,(2-h)\,K\rho_1}{\cancel{h}} = \frac{\varphi\,(2-h)}{\cancel{h}}$$

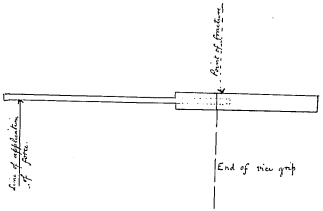
the resistance of the coil must equal that of the telephone + connections, while the telephone itself should have as high a resistance as possible: If $C = 18$, $+ b = 2.5$ Then $K = 194.3$

$$D = \left(\frac{194.3 \times 2300 \times 1.2 \times 10^{-6}}{150}\right)^{\frac{1}{4}}$$

$$= \left(\frac{1.943 \times 2.3 \times 1.20}{1.5}\right)^{\frac{1}{4}} \times 10^{-2}$$

$$= (357.6)^{\frac{1}{4}} \times 10^{-2}$$

$$= 4.35 \times 10^{-2} = 0.0435 = 0.017 \text{ low covering} = 0.010$$



Test of the Transformer #1
after placing in its box beneath the track. 24th Jany. 90.

With 6 volts at low volt terminal, the current to the track was 30 ampères, the day being mild + clear, = 180 Watts. With 20 volts 100 ampères of leakage or 2000 Watts lost power might be expected. This in excess of what was anticipated from the trials made on the laboratory premises with buried single rails.

Test of the Breaking strains of the new Meter zinc plates from samples supplied by Mr. Gladstone 26th Jany. 90.

The zinc plates tested were gripped in a vise so as to lie horizontal, and with the lug free. By means of a connection screw weights were applied at the screw thread near the end of the rod until fracture at the shoulder of the zinc took place. Eight trials were made as follows:-

No. of trial	Breaking weight	Weight of casting	Total breaking wt	Total breaking wt grams	Length of lever	Moment of couple lbs. × grms	Mean breaking wt	Mean breaking couple
1	66	13 lb	79	22400	7·2	16100		
2	68		81	23000	2·9"	16600		
3	112		125	35740		255000		
4	117		130	36900		26600	3280	28,540
5	64		77	21800		15700		
6	159		172	48800		35150		
7	92		105	29800		21500		
8	140		153	43400		31200		
			922	262500		188350		

Test of Car Track resistance when Transformer #1 running

E.M.F. at generator terminals (0·5 33000) = Current 8 amp. Activity.
After this had been applied for about 15 mins the current fell to 2 amp.
During this period the current in the secondary coil must have been about 300 ampères. Probably some screws had been left in accidental contact between center rail and his rod and this became destroyed by the strong current. P.D. at track 20·5 v.
Reduced generator pressure to (2·25 33000) = Current 2 amp activity
P.D. at track close by transformer 15 volts.
Took a res. of lead + ampère meter + coil = 0·135 ω and obtained current of about 110 ampères by transformer. At Tony corner distant 400 feet this current was 90 amp. = 0·158 ω = 0·02 for 400 feet of track = 0·005 ω per 100 feet = 0·00005 ω per ft = 5×10^{-5}
at the cemetery gate the current was 65 ampères = 0·231 ω = 0·096 2200 feet of track = 0·00044 ω per 100 feet = 0·000004 ω per ft = $4 \cdot 4 \times 10^{-5}$
a current of 500 ampères thro' 450 feet = 0·02 ω would drop 10 volts.
Each foot of the center rail without joints being 3 sq. ins. of iron should offer $1 \cdot 17 \times 10^{-5}$ ω. The outside rails offer would offer without joints about the same resistance each = $0 \cdot 59 \times 10^{-5}$ ω in parallel. So without joints the res. of one foot of track would be $1 \cdot 76$ ω $\times 10^{-5}$ instead of $4 \cdot 4 \times 10^{-5}$ 40%.

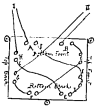


Diagram of connections Astatic Differential Troy Galvr.

On the 25th Mar. 1890 the compensating resistor of 22·6ω was removed and replaced after a refilling of with 31·7ω of double wound 0·002" copper wire. See p. 15 Book 2E

Tests of a certain material named Breslaw Compound for Bergmann &c:

Jan. 28th 90. This sample was in the form of a small disk, black material. It polishes well & apparently pressed used in a mould. is soft, has under this fole the appearance of slate on a fresh surface. It will not support a flame but catches fire in a flame with disengagement of gas, and a smell of burning gelatine. It takes a good shade very easily, but the substance is weak, and brittle.

Samples soaked in water, NH_4, NaO, HCl, H_2SO_4 & behaved badly but pieces exposed to a comparatively high temperature above the boiler 65°C. did not suffer.

Differential Astatic Galvr:

Resistance of individual coils 27. I. 90

A	858ω	B	737ω
C	1010ω	D	1007ω
E	999ω	E	984ω
F	846ω	G	744ω

28. I. 90 { Resistance of complete circuit A D E H I black 36.5 g ω=3 T.B. 23·8°C. T.G. Abt 23°C
, " " " B C F G. II white 36.2 g ω=3 " "

Added a compensating coil of 9·4ω to ⅌ II cct. behind the bof coil to effect the balance ⅌ I being in preponderation, also a spool of 22·6ω resistance in C.S. wire.

Repetition of Experiment on the Saturation of iron by transverse magnetic stress.

Jany. 29th The same box described on page 91 was rewound with 30 turns of silk covered copper wire 0·015" to 0·020" on all four sides. The resistance of each coil was 0·675ω @ 20°C. Preliminary results were obtained when rubber plates 0·198" (0·005) were inserted on each side of box between it and pole faces. The readings were with no current and with 18·37 amperes thro' magnet Saturation same as on previous occasions recorded. T.B. 25·5°C.

No. of Cct.	Direction relatively to magnetic effect	Current thro' magnet coils	res. ind.	leads	res. of coil	Rdg. for balance inf.	Inductance of coil	Res. in bulbs, galvr. cct.	Throw on reversal	φ	L
1	=	0	2·709	2·046	0·663	0·460	12·46	—	—		
2	+	-	2·721	2·046	0·675	0·440	11·97				
3	=	-	2·730		0·684	0·440	12·01				
4	+	-	2·725		0·679	0·425	11·58				
1	=	18·37	2·710		0·664	0·155	4·20	a	35		
2	+		2·722		0·676	0·060	1·63	25000	217·5		
3	=		2·731		0·685	0·160	4·37	0			
4	+		2·726		0·680	0·060	1·63	25000	190.		

1 C.C 1·4223 ω thro 0·40μ + gives 66 divs.

Experiments on the effect of an electric current traversing cotton cloth (thereby) rendering it waterproof. Jan 30th 90

Made a number of miscellaneous experiments following the lines shown by Mr B. Brevoort the day preceding. He showed that piece of cotton cloth dipped in plain water and pressed between tin surfaces became waterproof after a few moments submission to a current from a few cells traversing the cloth in the direction normal to its plane. He stated tin to be the best metal for the purpose, and that the effect was a function of the p.d. current pressure and time employed. There is a slight change of color noticeable in the cloth produced by the operation and drops of water thrown upon it after drying are repelled from its surface and tend to assume the spheroidal state. The electrodes employed by Mr Brevoort were disks of block tin about 4.5 in diam. and 0.5 thick. They were kept clean and plain, were pressed upon the cloth face to face by a hand grip and about 10 volt was the maximum emf employed. The time of current application varied between 5 and 30 seconds. Mr Brevoort said that he had used most metals for electrodes but had failed with platinum. Also that any considerable trace of acid in the water used for wetting the cloth produced failure.

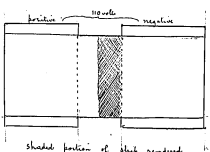
Repeated these experiments with various electrodes and qualities of cotton cloth. Found good results with zinc electrodes ~~but~~ and water but failed with the same electrodes and solution of $ZnSO_4$ as the immersion.

Will fow phy much in water. The action was very powerful at the anode the sheet on that side being markedly waterproof. The succeeding sheets were less so and finally the fourth or cathode sheet was scarcely if at all affected upon. This is in accordance with Mr Brevoorts results which show the oxygen electrode or anode to be the important electrode.

Jan. 31st Succeeded in obtaining the effect with strips of cotton between clamps The strips were about 2.5 broad and their length between clamps 2 to 8. The effect in these cases was observed (with zinc clamps) on the cathode half of side, and also under both clamps. 110 volt was the p.d. in these trials.

Feby. 1st Obtained some results with blotting paper between disks of tin, water immersion, and also some results with strips arranged as in yesterday's experiment with clamps, when soaked in solution of NaCl in H_2O. Failed with dilute H_2SO_4.

Took a strip 3 cms broad and about 7 long. This was moistened in tap-water and then layed across two small metal zinc plates connected with the 110 volt circuit and separated by 1.5cms. No upper plate or pressure was used to keep the strip in contact with these electrodes. The strip was cut diagonally to the mesh. After about three minutes a white line of some salt had formed across the strip parallel to the edge of the electrodes and about midway between them. On drying and immersing the strip, all that portion 0.5×3 on the cathode side of this demarkation line was waterproof, all on the other side being apparently unaltered.



Shaded portion of strip rendered water repellant

Succeeded in a series of twelve trials in obtaining very good waterproofing effects from two disks of blocks 5 in diameter × 0.3 thick, turned true in a lathe + brought smooth with the finest emery powder. The battery was 4 cells of 300 hr NiHO and 6 cells of Burnell's Leclanché in 2 series parallel i.e. 6 × 0.7 + 3 × 1.5 = 4.2 + 4.5 = 8.7 volts. The ammeter was the spring inst. up to 5 amperes. The time of current application was gradually increased with improvement up to 90 seconds commencing at 1 amp. + falling to 0.3. The pressure was 5500 or about 280 per sq. cm.

Repeated the best already recorded of this morning with two strips cut diagonally with the warp + woof. The length were 3 and 2½ respectively between edges of zinc electrode. In each case a white irregular line about midway and parallel to the electrode lines formed after some time. All the surface on the cathode side of this line was repellent more or less all on the anode side (+) was either not deflected or even attractive. Examined this white line under microscope. It appeared to be either due to or accompanied by much destruction of continuity in fibre which on the line seemed to be torn and irregular.

Feby 2nd Made a series of experiments on the effect of time on the production of repellent action employing constant e.m.f. and pressure. With tap water immersion two disks of tin above described, 7 volts + 5500 g. pressure gradually increased the time to 90 seconds at which + interval the best results were obtained. Current 1.4 to 0.4.

Next tried a series at constant time and pressure but varying e.m.f., with 10 seconds application and other conditions the same, found best e.m.f 6.77 volts (about). Reducing gradually lessened effect until with 10.8 volts it was very weak. At this last value however the effect of increasing the time to 60 secs was to make the effect result very good.

Tried the effect of placing a piece of cotton in a bottle exhausting the same and then forcing hydrogen gas through it. No result was obtained by this means when the cotton was put in wet or dry.

Continued experiments with strips lying across electrode using 115 volts. Repellent effects obtained in every case on cathode side extending usually from the electrode over to the demarcation white line usually about half way across. Obtained effect with two arc light carbons as electrodes also on − side. Obtained effect using immersion of solution 100 c.c. tap H.O containing 7 drops HCl conc.

Tried to obtain effects using water electrode. The strip was laid across insulating supports and zinc electrodes placed near its ends but separated by about 0.2. These gaps were filled with tap water. No result was obtained with plain water apparently from want of conduction, but on repeating with dilute acidulated water just mentioned, the result was distinct on the cathode side.

Strips were also tried thoroughly washed in strong HCl to remove the sizing and then washed out in NH_4HO. The conductive power of these strips in tap H.O was apparently very small but using dilute HCl, as above effect was obtained. Passed a current from 115 volts through 2000 and a single thread of cotton on a slide under the microscope. With a magnifying power of 220 no effect or change could be detected.

Armature 96 divs: # 9 B&S. 0.145" wire round in each div.
= 96 complete turns = 192 wires all round armature. Area: 0.040 - 0.055".
= 25 lbs. weight of wire approx. Commutator 96 blocks.

Field winding 63 lbs of # 17 B&S on each spool. 18.7 ω each @ 1.55 ω

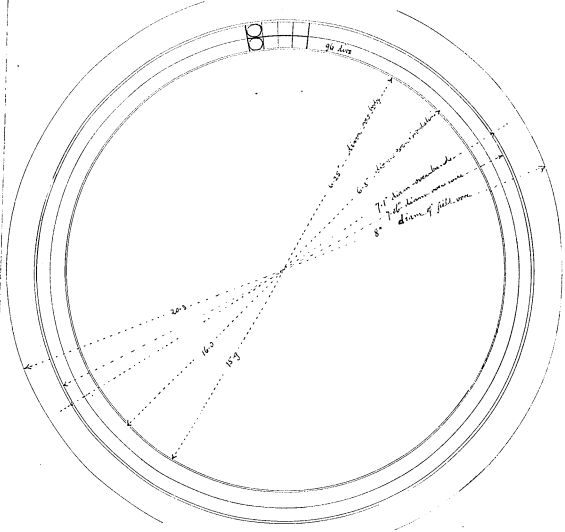
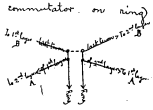


Diagram of commutator or ring disk at back of winding



Calculations for a 50 volt continuous and also alternating current dynamo of No. 14 Standard General Dimensions to utilize the parts that remain available from the Transformer.

The transformer when supplied by 960 volts and operating its own fields in series was made 1500 revs. of its armature, with this additionally large bore we may say 1900. It had 1728 wires on the drum and the flux was therefore

$$\frac{9.60 \times 10^{10}}{1.73 \times 10^{3} \times 3.0 \times 10^{1}} = \frac{9.60}{5.19} \times 10^{1} = 1.85 \times 10^{1} \text{ lines utilized.}$$

For convenience and to have ample margin we may take 1.0×10^{6} as the available flux to produce 50 volts. Then at 14.00 revs:

$$w = \frac{5.0 \times 10^{2}}{2.33 \times 10^{1} \times 1.0 \times 10^{6}} = 215.$$

As there must be employ the 96 bar commutator be either 192 or 288 wires we may take 192 which will represent one complete turn to each division of the commutator.

The circumference over insulation = 19.8" and this after deducting for fibre and insulating paper leaves 17.4" ÷ .96 = 0.181" for the covered wire = # 9 B&S 0.145" allowing for thick wire. The thickness of two such layers will be 0.35" and over bands 0.4", which will make external diameter over bands 7.1", and if fields are unaltered the clearance would be 0.45". # 9 B&S. happens to be the exact size employed with # 14 O.S. machine in 100 complete turns.

By disconnecting the last turn of both layers and reversing them mutually the machine becomes an alternator giving 100 volts at the peak of the wave and $\frac{200}{\pi} = 63.7$ volts mean at $\frac{14.00}{60} = 23.3$ ~ per sec.

The field winding may be the same as that employed for the 125 volt machine except that the magnets will charge themselves at 50 volts in parallel and will be charged in series from the 110 volt set when the dynamo is used as an alternator.

If the field be bored out a few to the same diameter as the ordinary # 14, the voltage will increase to 100 self exciting and the machine becomes practically a O.S. # 14.

Calibration of Obach Single Ring. 7. 12. 89.

Silver Voltameter 25% neutral solution of $AgNO_3$. Plate 9.8 × 3.5
About 2 amperes was passed through this and the ring for 300 seconds. Deflection. 0.385

Weight before test	Anode	Cathode
	16.9287	12.3226
	16.3712	12.9790
	0.5555	0.6564

Mean 0.6560

0.656 ÷ 300 = 0.0021867 gms per sec.
0.0021867 ÷ 0.00118 = 1.956
0.385 ÷ 1.956 = 0.1969 say 0.197

Further experiments on the effect of electric currents traversing cotton cloth thereby rendering it waterproof. cont. from p. 150.

3.II.90 Employing two platinum electrodes repeated experiment of previous day – A short strip of cotton was soaked in conc. HCl for a few minutes. Then washed out and soaked in dil. NH_4HO and then washed out again before immersing (after being dried) in solution of HCl in half water 7 drops in 100 c.c. This strip about 2.5 × 2 was laid horizontally between two parallel edges of non conducting material, bridging them so to speak and the ends of the Pt electrodes brought up to within 0.2 of the ends of strip. The intervening non-conducting spaces were then filled up by a few drops of the dilute HCl and the 110 volts applied. The conduction was apparently very feeble. But in application of 5 to 10 min. results of some interest indicating repellent effects near cathode, and in one instance a solution of madder took depth on the portion of strip, indicating presence of a mordant. The effect however was very feble and manipulating between the fingers was sufficient to extinguish it.

On applying current between lead electrodes for a few moments through a strip moistened in tap water, the rinsing of the strip in solution of $K_2Cr_2O_7$ was to produce evident appearance of $PbCr_2O_7$. No such appearance was produced by mere pressure of wet strip between electrodes without current.

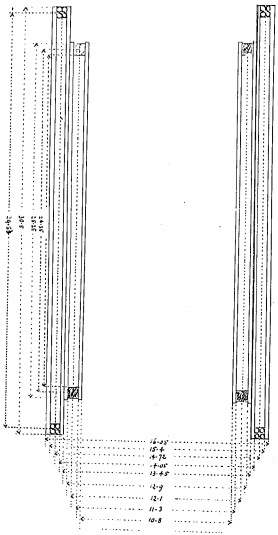
4.II.90 Using lead plates and bridging them with strips moistened in water and very dil. HCl obtained a series of consistent results on dyeing, immersing in $K_2Cr_2O_7$ sol: as follows—

On the + electrode the $PbCr_2O_7$ attached with increasing strength up to the edge from that point it diminished to about 2/4th intervening distance where it nearly disappeared. This gave way to a very distinct bright yellow or brown hydrogen band terminating at the edge of the – electrode and over the – electrode there was no effect.

Between electrodes of platinum using a few volts transversely and moistening with tap-water there was very apparent attraction effect on dyeing, with dyeing action in the case of a mixture of logwood and madder. With carbon plate first on + and then on – side with opposition of platinum partly repulsive and partly attractive effects were obtained.

Current strength available in Galvanometer Room from Low Tension Dynamo.

Joined up the 1500 ampere meter with the large platinoid strip resistance and the Bus bars in galv: room. Obtained a current of 280 ampere with about 5 volts terminal p.d. at dynamo and about 450 ampere - - 8 - - - -



Calculation of the Constants of the Thory Standard Double Coil Galvanometer on last page.

The fundamental equation carried to a first approximation is

$$m l H \sin\theta = \frac{m l n \gamma \cos\theta \times 16\pi}{5\sqrt{5}\,A} = \frac{4.49\, n \gamma \cos\theta}{A}$$

$$\therefore n = \frac{H \tan\theta\, A}{4.49\, \gamma}$$

For the large ring and thick wire 1 amp. ($\gamma = 0.1$) gives 53° of which the tangent is 1.327. Taking H at 0.187

$$n = \frac{0.187 \times 1.327 \times 14.7}{4.49 \times 0.1} = 8.12$$

n may therefore be accepted as 8. i.e. 2 layers on each ring. The ext: diameter being 30.5 and the width of the coil being 0.675 the int: will be 28.150 and the diam: of the mean 28.825. The distance between the mirror planes should be 14.41 and is actually 14.7. Neglecting this error we have accurately

$$H \tan\theta = 8\gamma \left\{ \frac{16\pi}{5\sqrt{5} \times 14.5} \left(1 - \frac{1}{60}\,\frac{0.675 \times 0.675}{14.5 \times 14.5}\right) + \frac{0.0512 \times 3.1416 \times (28.825^2 - 8 - 5)}{3\sqrt{5} \times 14.5^3} \right\}$$

$$\frac{H}{\gamma} \tan\theta = 8 \left\{ \frac{50.2656}{5 \times 2.237 \times 14.5} \left(1 - \frac{3.4556}{12618}\right) + \frac{0.0512 \times 2.237 \times 8.4556}{6.4 \times 10^5} \right\}$$

$$= 8 \left\{ \frac{50.2656}{162.11735} \left(1 - 0.0000036\right) + \frac{0.05224}{0.00064 \times 10^5} \right\}$$

$$= 8 \left\{ 0.31006 \times 0.999964 - 8 \times 10^{-5} \right\}$$

$$= 8 \times 0.31004$$

$$= 2.48032$$

$$\therefore \gamma = \frac{H \tan\theta}{2.48032} \quad \text{or} \quad 0.4032\, H \tan\theta \quad \text{(abs measure)}$$

$$\text{for } H = 0.187 \quad = 7.540 \tan\theta \times 10^{-2} \quad \text{(abs. measure)}$$

For the small rings A is approximately 12.

$$\text{and } n = \frac{0.187 \times 0.095 \times 12}{4.49 \times 0.0001} = \frac{1.87 \times 0.95 \times 1.2 \times 10^{1}}{4.49 \times 10^{-4}} = 475$$

n should be divisible by 30 nearest number is 480 next 450 & 510

If there are 15 layers of 15 turns then n = 450
" " 16 " " 15 " " n = 480
" " 17 " " 15 " " n = 510

mean it may be taken at 24.4 ∴ mean circ = 7.666 = 2.515 ft.

The res: of the fine wire ext: = 51.5 the diam: of the wire is 0.0155

" # 26 B.S. = 24.61 ft per " = 1267′ ÷ 2.515 = 504 turns.
" # 27 B.W. = 24.9 " " " = 1277′ ÷ 2.513 = 508 "

If there were only 16 layers instead of 17 there would be 480 turns and at 2.515 ft = 1207′ ÷ 24.9 = 48.6 " a difference of 2.9 " This is too large an error to be probable. What makes this number 17 more likely is that in order to make the galvanometric constant C_3 remain the breadth : depth :: 31 : 36 if channel for winding no: of turns on one layer should : no of layers :: 31 : 36

∴ no: of turns on one layer should be 15
and according to this ratio with no: of turns = 15
no: of layers should be 17.4

and 17 may have been adopted. In which case

$$\frac{H}{\gamma} \tan\theta = 510 \left\{ \frac{50.2656}{11.185 \times 12.175} \right\}$$

$$= \frac{25635.4656}{136.1774}$$

$$= 188.2505$$

$$\gamma = \frac{H \tan\theta}{188.2505} = 5.312 \times 10^{-3}\, H \tan\theta \quad \text{(abs. mea)}$$

and for H = 0.187

$$\gamma = 9.938 \times 10^{-4} \tan\theta \quad \text{(abs measure)}$$

On the Connections and output of an Alternating current Dynamo on the plan of the 200 ampere Edison Multipolar.

At 1000 revolutions, with all its coils in series the machine should be capable of delivering 1200 volts mean alternating e.m.f. = $\frac{\pi}{2} \times 1200$ or 1890 volts continuous equivalent, and there are 8 sectors = 236 volts per sector, practically double the winding necessary for 115 volts. There will be 4 complete periods per revolution = 4000 periods per min = 66·67~ per second.

Trial of the Rock-Drilling Machine wounded as shewn on page 26. 5th February 1890.

The current supplied to the armature was about 16 amperes and the e.m.f. 62·5 v. res. = 3·9 ω hot. Current in field reckoned at 4 amperes. Total current 20 amp. energy 1250 Watts. Magnet and armature heating excessively.

To measure the work developed by the machine arranged a ballistic pendulum weighing 116 lbs (52600) and of radius 98" (249). The mean thrust of the drill rod was found to produce an excursion of about 9" (22·9). This is equivalent to a lift of 2·1 cms., and the work done 110500 ergs = 108400000 ergs = 10·84 Joules. The machine was found to be capable of producing 180 blows or 360 reciprocations per min. = 6 per second = 65 Watts. The efficiency is thus 0·052. In reality during reciprocation the current flowing through the armature would be diminished but on the other hand the blows at this speed would probably be lighter than when delivered slowly, as a matter of observation they were lighter. Consequently this efficiency is not likely to be far wrong.

With 4 complete turns of wire round the central core the throw of the ballistic galvo was $-160 + 156 = 156$ mean or $\frac{156}{8} = 19{\cdot}75$ divs for a single turn flux with 50,000 in circ. 0·4014 & charged by 1·43 volts or $0{\cdot}578 \times 10^{-7}$ abs. p. gave 70 divs so that 1 div represents $8{\cdot}26 \times 10^{-10}$ p. + 19·75 divs represent $163{\cdot}2 \times 10^{-10}$ or $1{\cdot}632 \times 10^{-8}$ p. $\therefore \Phi = 1{\cdot}632 \times 10^{-8} \times 5{\cdot}53 \times 10^{8}$

$= 9{\cdot}024 \times 10^{5}$

The diam of the central core round which the wire is wound, is 3·42" = 8·69 cms. an area of 58·6 sq. cms so that

$$L = \frac{9{\cdot}024 \times 10^{5}}{5{\cdot}86 \times 10^{1}} = 15{,}400.$$

Measurement by Cathetometer of the Diameter of a steel Disk at 16°C 7th February 1890.

Upper limit	72·017	72·020	72·024
Lower "	62·326	62·324	62·316
Weight	(3) 9·691	(3) 9·696	(1) 9·708

$3 \times 9{\cdot}691 = 29{\cdot}073$
$3 \times 9{\cdot}696 = 29{\cdot}088$
$1 \times 9{\cdot}708 = 9{\cdot}708$
$9 \mid 67{\cdot}869$
$9{\cdot}696$

The diameter of a disk 12" in diam = 9·702 cms.
9·696
0·006

0·006 cms = 0·0024 deficiency.

Calculation of the Copper Required to Transmit power on the 3 wire system to 20,000 lamps from Canal St. to Fulton St. N.Y. a distance of 4200 feet by a feeder or feeders with 15 % drop on the same.

The current to supply each lamp will be 0.4 ampere and the p.d. at the lamp will be 120 volts @ 1% drop in the mains this will be 121.2 say 121.5 volts at feeder extremities & at 15% this will be 143 volts at feeding two bars, a fall of 21.5 =

The current will be 10,000 × 0.4 = 4000 amperes on the outside. Then r = 21.5/4000

= $\frac{1}{200}$ th of 1 ω roughly 0.005375 ω

= $\frac{1}{840000}$ ω per ft

= ~~0.0000~~ 1.256×10^{-6} ω per ft.

1 c. mil foot has 10 ω.

~~1.~~ 8,400,000 mils will be needed.

the weight of this is 8.4 × 3.0 = 25.2 lbs per foot for +

= 25.2 . . . . –

30% = 7.6 . . . . o

80.0 . . . for all

The total weight would be 240,000 lbs. or 120 tons

Test of some short lengths of Johnson tubing for Conductors, made at Mr S. H. Johnson's instance

A series of different samples of tubing made from paper soaked and hardened in some special liquid was brought to the Laboratory on the 13th January.

These tubes were cut into convenient lengths and soaked in water. Each was closed at both ends with a cork well luted with paraffine wax and filled with common tap-water. A g.p. covered wire was tightly through one cork and gave electrical communication with the interior. The tubes were then left in a stoneware tank full of water.

On the 6th of February one of these tubes gave the following test.

Length 21" (53) Weight 93 grammes
Diam. int: 5/8" 1.56
ext: 13/16 2.0

Constant. Ballistic galv. 1 Ayrton, 450,000 ω. S. 591 ω. 100 divs.
Galv 5300 ω
Shunt 591 ω.

$\frac{9+5}{3} = \frac{5891}{591} = 9.97$

9.97 × 30 × 100 = 29900.

Deflection on sample 30 Ayrton no S. 117 divs.

$R = \frac{29900 \times 0.45}{117} = 115\ \Omega$ abs.

or about 40,000 ω per mile.

Test of the Sewing Machine wound as calculated on page 142 with the battery altered as there described.

7th Feby. 90.

10 Phonograph K.HO 300 amp. hr. cells were prepared specially at Silvertown with double copper and triple zinc plates, thus doubling the active surface in each cell.

EMF of 10 cells 7.35 v. Res: of field 3.4 w. Res. of arm. 0.33 w. Res. of battery 0.33 w. (0.234 v.)

No. of hist.	Condition of motor	P.D. at M.T.	Current in ct.	Current in field	Current in armature	Power in ct. in watts	Power lost in field	Power lost in armature	Power developed in arm.	% eff.	Armature Speed in revs. per min.	Field of pole tips in lines per sq. cm.	Power of magnet in watts	Volts per turn
1	Normal	4.92	4.29	1.45	3.04	10.9	7.14	3.8	11.9	0.53	465	2.43	872	1.01
2	Connected but open circuit	4.05	6.63	1.19	5.44	21.9	4.8	9.9	12.2	0.31	288	3.20	570	1.81
3	2 flys. on	4.05	6.63	1.19	5.44	21.9	4.8	9.9	12.2	0.31	265	3.20	498	1.81
4	4 flys. on	4.09	7.14	1.20	5.94	23.3	4.9	11.8	12.5	0.29	264	3.26	449.5	1.95

Res. of galvo + leads 0.02 w. avg. vol: ratio of sewing machine shaft to motor shaft 1.875

No. of hist.	Power in Circuit	E.M.F.	Power in mot.	P.D. at M.T.	Power in arm.	Armature emf.	Speed rev. per min.	Calculated speed rev. per min.	% eff. induction				
1	33.0	7.35	22.1	4.92	11.9	3.91	7.75		0.54				
2	48.7		26.9	4.05	12.2	2.24	4.8	4.4	0.45				
3	48.7		26.9	4.05	12.2	2.24	4.4	4.4	0.45				
4	52.5		29.2	4.09	12.5	2.11	4.4	4.2	0.43				

Test of Inductance of Phonoplex Receivers

No.	Saw	Phone	Bridge	Res.	Capy	Inductances Seconds	Inductances Kilometers.
1	In	(Ordinary)	1000/10	99.98	0.80	0.0798	798
2	Out				7.337	0.1336	1336
3	In	Special with laminated magnet core		96.19	0.70	0.0673	673
4	Out				1.208	0.1162	1162

Test of the original Schenectady Standard Condenser ½ ϕ by Elliott Bros, after overhaul + resetting.

When still hot from molten paraffine wax 0.3907 ϕ

After cooling down to about 20°C. 0.4157 ϕ.

On the 20th February 1890 by comparison with Elliott Bros: divided unit $\frac{1000}{1110}$ resistance 0.417 ϕ reversing bridge arms 0.4157 ϕ 0.005 ϕ difference balance at about 100 revs per min of handle slow speed by about 2 divs.

Mean capacity 0.4175 ϕ

Data concerning the new Edison Composition Electric Lamp at 18 per h.p. elect.

18 16 c.p. lamps = 288 lamps for 746 Watts = 2.59 W. per c.p.
at 120 volts = 6.216 amperes for 18 lamps = 0.345 amp. each.
The resistance of each lamp (hot) would be = 348 ω
The life of that lamp would be about 900 hours.

The old lamp had 15 lamps of 16 c.p. = 240 c.p. per h.p.
= 3.11 Watts per c.p., the resistance hot was 243 ω and
the current 0.452 amp. at 110 volts
Bamboo filament.

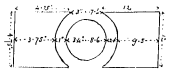
There is also a brand of composition lamp marked Edison #20 which tested as follows:—
125 volts amperes 0.3 per lamp = 319.3 c.p. per h.p. or 19.95
lamps of 16 c.p. per h.p. = 2.34 W. per c.p.
Average life 832 hours. Res. hot 419 ω.
This lamp is at present in reserve.

Test of a sample of insulating material for Messrs Bergmann & Co. N.Y.

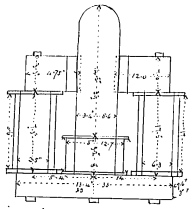
Received two moulded samples one black the other red and spangled, of a substance named Electroid.
It burns very much like Breslaw compound is very weak & brittle does not nourish a flame, and smells when burning like sealing wax. The substance immediately surrounding the burning portion is soft and plastic. It takes a very poor thread but polishes well.
Samples were immersed and tested in the usual manner

Once in plain water	Apparently not much hurt	
" " dil. NH_4HO	This slightly darkened	
" " - H_2SO_4 sp.	Apparently unaltered	
" fused in wet sand	" "	slightly more brittle
" in kerosene oil	" "	"
" over boiler @ 150°F	" "	"

The plastic condition is reached about 300°F (149°C)

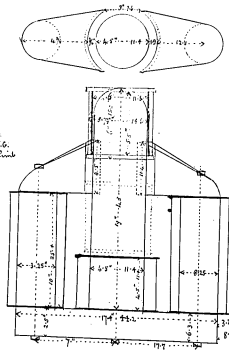


Section at right angle to axis through poles.



Section in plane through three axes.

Section of existing magnets 1/6 actual size.



Magnets
15 lbs 2 oz. of #16 magnet B.W.G.
S.C.C. wire on both each limb
68½ lbs. in all
On outside core ¾" depth
8½ layer of 130 turns
= 1130 turns = 5700 A.T.
On inside core 1" depth
14 layers of 50 turns
= 700 turns = 3570 A.T.
Total A.T. in each half of circuit 9270.

Section of proposed magnets 1/6

Electrical Design of the Rock-Drill Machine as modified from that given on page 26 the test of which is recorded on page 154.

(158)

The existing apparatus has a central core 3" in diam: and outside core 2½" in diam. To obtain greater power these may be increased to 4"·5 and 3·5" respectively (10·5 and 8·9). The present length of outside core is 7" (17·8). This may be lengthened to 10".

The present outside cores have 10 layers of 120 turns = 1200 turns on the outer inside the layers of 141 turns = 570 turns.

The surface of the new outside cores will be approx: 34 × 25·4 = 850 sq. cms and allowing 10 sq. cms per Watt = 85 Watts each. The circumference of the pole space is about 4·7 cms − 15 = 32 = 16 cms. for each face × 11·4 . 182·4 sq. cms. The reluctance of this is $\frac{240}{8.9} \times \frac{1.9}{200} = 0.0095$ lines. The area of the central core is 102 sq. cms and at 18000 lines = 1,840,000 in all or 920,000 to be generated by each limb.

$\therefore \quad mmf = 9.20 \times 10^5 \times 0.095 \times 10^{-8} = 8.74 \times 10^3$

$\text{a.t.} = 6.95 \times 10^3$ say 7000.

At 50 volts terminal p.d. 1·7 amperes will be required limit for heat and the number of turns = 4120.

The resistance will be 50/1·7 = 30 ω hot = 25 ω cool.

coiling space allowing ¾" (1·9) depth of coil = $2.5 \times 0.785 \times (12.7 - 8.3)$

$19.6 \times (146 - 68.9) = 19.6 \times 77.1 = 1510$ a.c.

$d = -0.02 \pm \sqrt{0.0004 + 0.00153\sqrt{\frac{1510}{25}}}$

$0.00153\sqrt{60.4}$

0.00153×7.77

0.01189

$0.01229 \qquad 1.229 \times 10^{-2}$

1.109×10^{-1}

$= -0.02 + 0.111$

$= 0.091$ cms $= 0.036''$ = #19. B.S. @ 125' per ω

= 3110 feet. The mean turn = 4" = 1' roughly ∴ 3110' are about 3100 turns.

The coiling space of the central core is $0.785 \times 11.4 \times (26.9 - 12.0)$ allowing 25%

$= 0.785 \times 11.4 \times 13.9 = 12.25$ ...

The total magnet coiling space is therefore 2 (1510) + 1225 = 4265

Taking the coiling space on each limb as 1500 a.c., and putting the magnets in series, the p.d. on each is 50/2 = 18·67

The current for 55 Watts is 5·4 amperes so that the res: = $\frac{18.67}{5.4}$ = 3·27ω

For this result $d = -0.02 \pm \sqrt{0.0004 + 0.00153\sqrt{\frac{1510}{3.27}}}$ = 2d $\sqrt{\frac{1510}{3.27}}$

$\sqrt{462} \qquad \sqrt{521}$

21·5 22·8

$+ \; 0.0329 \qquad 0.0349$

$\sqrt{0.0333} = \sqrt{3.33 \times 10^{-2}} \qquad 0.0353$

$= 1.825 \times 10^{-1} \qquad 1.879$

$= 0.1925 \qquad 0.1879$

$= 0.163$ cm $= 0.064''$ #14 B.S. $\qquad 0.169$ cm $\quad 0.066''$ #16 B.W.G.

3·27ω @ 5·4 = 17·68 lbs = 145·5 lbs in all

2·9 ω @ 5·234 = 15·18 lbs = 125·5 lbs in all

15·15 × 7·19 ft per lb = 1187 ft = 1100 turns or 5600 a.t.

The no: of turns in 1 layer on outside core = 9·8 ÷ 0·075 = 130 the mean turn has a diam: of 1·05" = 137' per layer = 8½ layers = 0·7" diaf.

The no: of turns in 1 layer on inside core = 4 ÷ 0·075 = 53 the mean turn has a diam: of 1·6" = 168' per layer = 14 layers = 1·0" diaf = 740 turns

The armature will have a surface of about $3.14 \times 14.6 \times 14 = 640$ sq. cms. and at 5 sq. cms per Watt = 128 Watts, = 42.6 amp. @ 50 volts. 4 amperes will however in spite of the heat be necessary = 12.5 w. The breadth of the winding space is 5.5" 3/4 in. of which 3.7" can be utilized. If 3/4" be the enlarge, the clearance 0.05" on interior and 0.13" exterior = 0.18" leaving 0.37" for wire and cylinder. Allowing 0.17" for cylinder leaves 0.14" for winding space. The coiling space is thus

$$0.785\,(12.6^2 + 14.6^2)\,9.3 = 0.785 \times 9.3 \times (213 - 159) = 0.785 \times 9.3 \times 54 = 394$$

$$d = -0.02 + \sqrt{0.0004 + 0.00153\sqrt{\frac{394}{10}}} \quad \text{(bde)}$$

$$394 \quad 9.4 \quad 6.28$$

$$+ \; 0.00061$$

$$0.0400 = 1.0 \times 10^{-2} = 0.1 \text{ cm.}$$

$$= 0.08 \text{ cm.}$$

$$= 0.032'' = \#21 \text{ B.W.G.} = 0.0444'' \text{ covered.}$$

$$= 120 \text{ turns per layer.}$$

$$= 999 \text{ sq. } 1000 \text{ ft. The mean turn will be } 1.4 \text{ ft}$$

$$= 700 \text{ turns} \times 4 = 2800 \text{ A.T.}$$

10 w of #21 B.W.G. @ 0.307 lbs per = 3.07 lbs.

Determination of the winding for the Siemens alternator to deliver 1000 volts

As there are 8 poles there are 4 complete periods per rev: so that at 1500 revs. per min there are 100 ~. The machine gives normally 200 v. at that speed from coils of 16 turns 11 layers deep = 176 turns ∴ for 1000 volts 880 turns are needed. If n turns be in the layer the no: of layers should be $\frac{n}{16}n^2$ ∴ $\frac{n}{16}n^2 = 880$ or $n^2 = 1250$ $n = 36$. and layers 24. The breadth of the coil is 1.6" ∴ $\frac{1.6}{36} = 0.0444''$ covered = 0.032" copper wire = No. 21 B.W.G. D.C.C.

As this wire can scarcely be expected to carry 10 amperes it will be necessary to encroach upon the field. If 3 wires be employed their diameter covered will be 0.066" = 0.052" = #16 B.W.G. and double field will be needed. 16 layers + 24 turns per layer. ~~If 3 wires be~~ The weight of wire on each ~~spl~~ is at present about 7½ lbs = 60 lbs for the whole armature and with the new wire the weight will be a little less = 3 w per coil = 24 w per no: of machine.

In order to improve the existing apparatus the polar heads may be extended to 6" face, and the entrefer reduced to 0.75". The armature will be 7" long (17.5) and its bear diam 3.6" (9.2). The diam: of the polar bore 4.9" and of the external armature 4.7" = 12.0 ∴ the coiling space will be

$$0.785 \times (12^2 - 9.2^2) \times 17.5 = 0.785\,(144 - 84.6) \times 17.5 = 0.785 \times 17.5 \times 59.4$$

$$= 816 \text{ c.c.}$$

The resistance should be about 10 w

$$d = -0.02 + \sqrt{0.0004 + 0.00153\sqrt{\frac{816}{10}}}$$

$$816 \quad 9.03$$

$$0.04392$$

$$0.0442 = 4.42 \times 10^{-2}$$

$$= 4.42 \times 10^{-2} = 0.0400 \text{ cm.}$$

$$= 0.040'' = \#19 \text{ B.W.G.} \quad 0.052'' \text{ cov.}$$

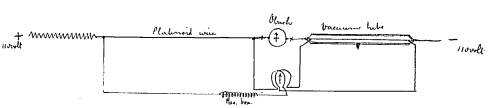
10 w @ 0.31 lbs. per w = 9.4 lbs.

The depth of winding will be 1.4 cm = 0.55" = 10 layers.

The mean turn = 10.6 cm = 4.3" → 13.5" circ. = 1.1'

120 turns per layer = 132' + 1200 turns = 1320' × 5.55 × 10⁻³ = 7.7

15 lb = 45½ in. = 8½ = 1 lb. 14 = The a



$22.4 - 15.5 = 6.9 \times 0.03 = 0.207 = 1.00207$

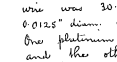
$\frac{4194 + 3718}{3718} \times 1.00207 = \frac{7912}{3718} \times 1.00207 = 2.1324\,\omega$ @ 25°C

Platinoid wire between offsets.

Experiments on the Conductance of Copper at different temperatures.

Febry. 11th. With Fessenden.

Took a glass tube of 2 cms. ext. diam. and 30 cms long, closed at each end, exhausted, and supporting a fine copper wire (bare) diam. 0.002", in its axis. The length of this wire was 30.5 approx. and it was heated with a platinum wire 0.0125" diam. & 2 cms long in glass thus



One platinum wire carried the current and the other served as a pressure wire for carrying back the p.d. to a galvanometer. The object of the experiment is to ascertain the temp. coeff. of copper beyond dispute and also the temperature of first luminosity. The measurements made can only determine one when the other is known but from such data as are already in existence or may be by us determined the results may throw light on both.

The current was supplied from the 110 volt circuit and was regulated by a fine wire res. box. It was found that about 1.25 amperes had to be passed through the wire in the vacuum tube in order to bring it to first luminosity. The tube was supported horizontally near its end in the photometer and the temperature at the commencement of the experiment was 26.6°C as shown by a normal thermometer supported close to it in air. The Edelmann differential galvanometer was used 4.5 volts on its coils in series giving about 0.5 div. Its resistance by bridge was $\frac{1000}{1000}$ T.B. 25.2°C. 5475 ω both coils.

$\frac{19}{6 \times 55 \times 0.03}$ 10 ω temp wr. $= \frac{5475}{2} = 2742\,\omega$ coil

When a feeble current of about 0.1 or 0.15 amp. passed through the circuit balance was obtained with 8290 ω in the standard res. cct. This standard was a platinoid wire 70 long and 0.066 (.002) in diam. on which two pressure wires were soldered 64.5 cms apart. The resistance of this wire wound in a helix was subsequently found to be 2.13 ω. The above balance was obtained with a potential deflection of ± 102 div and 0.5 div. could have been appreciated. It is probable however that this measuring current itself raised the temperature of the wire above 26.6°C, and steps will be necessary in future to avoid this source of error.

By several trials it was found that at first visible luminosity the balance was just 1520 ω. The increase of res. was thus in the ratio $\frac{2738 + 8290}{2738 + 1520} = \frac{10968}{4258}$ $= 2.576$ from the temp. of first measurement something above 26.6°C to the temp. of first noticed luminosity.

The room was dark during these experiments. The shutter all closed and all lamps extinguished in one instance, one covered lit in others.

Febry. 15th. Measured res. of platinoid standard with the aid of astatic differential galvanometer and Elliott 1 ω. Res. of galv. both coils in opposition $\frac{1000}{1000}$ T.B. 27°C 7436 = ords. Balance between 1 ω @ 22.2°C in H.O bath, wire when latter had 4192 ω in its coil cct.

$\frac{9.105 \times 2.132}{2.710} = 7.162 \;/\; 2.4144 = 2.968 \qquad 1.968/.006 = 4814.8°\,C.$

$\frac{9.045 \times 2.132}{2.710} = 7.151 \;/\; 2.4144 = 2.961 \qquad 1.961/.006 = 4841.0°\,C.$

$$\begin{array}{lcl} 2.636 & \text{Wt } 3 & = \quad 7.908 \\ 2.652 & \cdot\ 1 & = \quad 2.652 \\ \hline & & \quad 10.560 \\ & & \quad 2.640 \end{array}$$

$1 + D \cdot 0.004406 \times 23 = x$

$\frac{1.0938}{1.0938} = 2.644 \qquad \frac{7.191}{2.4144} = 2.979 \qquad \frac{7.2445}{2.4144} = 3.000$

$\frac{2.001}{.006} = 4937\,C$

$1 + 0.004406\,x = 2.979$

$0.004406\,x = 1.979$

$x = 4487.5°\,C.$

Res. of wire being 2.64 ω at 28° C taking the coeff for temp. as 0.388%

$x(1 + 23 \times 0.00388) = 2.64$

$x(1 + 0.08924) = 2.64$

$x = 2.64 / 1.08924$

$= 2.4244\,\omega$ res. @ 0°C

The results at first visible radiance were

				ω^2
7.158	Wt 2	.316	6.033	9.9×10^{-2} 19.8
7.160	· 3	.480	0.030	9.0×10^{-2} 27.0
7.245	· 3	.735	0.0825	29.2×10^{-2} 87.6
		1.531		136.4×10^{-2}
		.191		

$0.67145 \sqrt{\frac{134.4}{8 \times 7}} \times 10^{-2}$

$= 0.1686 \times 11.59 \times 10^{-2} =$

$= 0.1686 \times 1.159 \times 10^{-2}$

$= 1.954 \times 10^{-2}$

$= 0.0195 \qquad 0.02$

res. at first visible radiance $= 7.191 \pm 0.02$

Ratio $\frac{R_{vis}}{R_{0°C}} = \frac{7.191}{2.4244} = 2.967.$

Experiments on the conductance of copper at temperature of first visible luminosity. ente from preceding page

15th February 1890.

21.00 Res. of both coils astatic diff. galvo. 7320 ω @ 23°C T.B. Temp. room air 23°

. . . . Edelmann . 5412 ω . . . .

Temp. of air near tube in photometer case 23.1°C.

Dimensions of this tube as near one as follows:—

Length end to end 34.5. ext. diam. 2.1. Length of wire between supports 30.4 cms. Wire copper 0.0015" diam. that had been covered with silk at Schenectady but here dissolved of its covering. Portions of wire were closely axial in tube. When luminous the wire dropped heavily at each end and may actually have touched the glass.

It was ascertained that a current of 0.36 amp. through this wire rendered it just luminous, by one observation of Black. (0.072 cm)

When cool 8.65 ω added to wire balanced the 2.132 ω of standard platinoid res. on astatic diff. galvo. with feeble current diff. 165 ± reading to 10. Res. of wire cool (23°C or closely thereabouts) $= \frac{2.132 \times 4525}{3660} = 2.636\,\omega$

On the d.b. galvo. balance was obtained with 660 ω added to tube deflection ± 92.

$= \frac{2.132 \times 3366}{2710} = 2.652\,\omega$

The wire was then brought up with all lights in the room extinguished to first visible radiance by passing current from the 3.5 volt dynamo in series with 4 Leclanché cells (2.8 v) or about 6.3 volts in all through tube, standard res., galvo. and a platinoid wire with sliding contact. End of wire watched.

Results for balance with d.b. galvo. were as follows:—

Observer at galvo.	Observer at Photometer	Balance	Res. galvo. etc			
H	F.	6610	9320	(1)	9320	
		6400	9110	(2)	18220	
		6320	9030	(3)	27090	
F	H	6365	9055	(4)	9055	
		6465	9175	(5)	9175	
		6365	9075	(6)	18150	
				10	98010	
					9101	

Mean res. hot $\frac{9100 \times 2432}{2710} = 7.158\,\omega.$

Ratio $\frac{R_{hot}}{R_{0°C}} = \frac{7.158}{2.644} = 2.711$

The cooling seemed to take place very rapidly during the first few moments but a long time appeared to be required to reduce the last few degrees of temperature elevation.

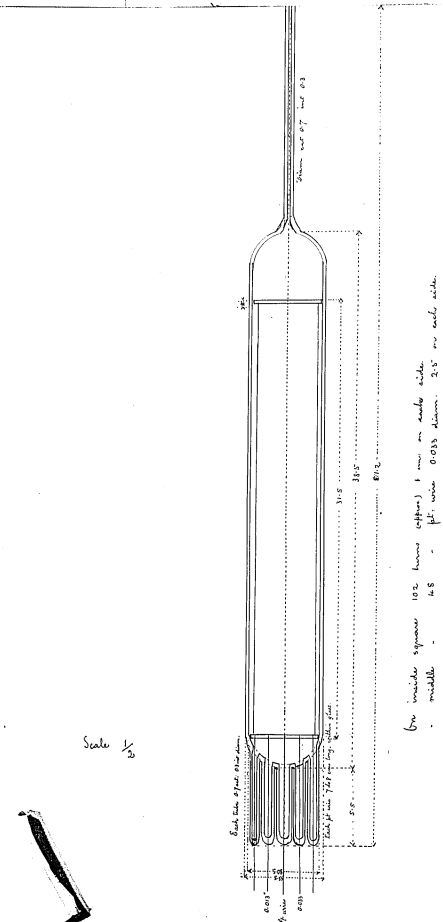
Made sensibility of astatic nearly 5 times greater by controlling magnetic system, and some 30 mins. after taking the res. hot observed Balance on astatic galvo. 1.06 g. 3.6 cm R. $\frac{2.132 \times 4730}{3660} = 2.756\,\omega.$

. Edelmann . 500 ω + 3.6 cm R. $\frac{2.132 \times 3510}{2710} = 2.762\,\omega$

Wire was then brought up to just visible radiance with following results all lights in room extinguished. Centre of wire kept watchful.

No.	Observer at Galvo.	Observer at tube.	Balance	Weights altered by observer	Res. in galvo. etc.	Wt × Res.	Res. of wire	Ratio $\frac{R_{vis}}{R_{0°C}}$
1	H	F	6660	(1)	9370	9370	$\frac{2.732 \times 9269}{2710}$	
2			6555	(1)	9265	27795		
3			6500	(2)	9210	46050		2.744
4			6640	(2)	9350	46750	7.245 ω	
5			6450	(2)	9160	73280		
6	F	H	6700	(1)	9410	9410		
7			6400	(3)	9100	18200		
8			6300	(3)	9000	27000		
				28	9265	257855		
						9209		

Mean


Scale 1/20
Platinum wire 0.5" long 0.03
Platinum wire 0.5" long 0.03
Platinum wire 7.5" long 0.03
Platinum wire 7.5" long 0.03
Platinum wire 7

Res. of G. 5250 ω

75.4 divs given for 5.975 × 10⁻⁸ at 40

1 ω = 7.924 × 10⁻¹¹

105,250 ω = 1.0525 × 10⁻⁶

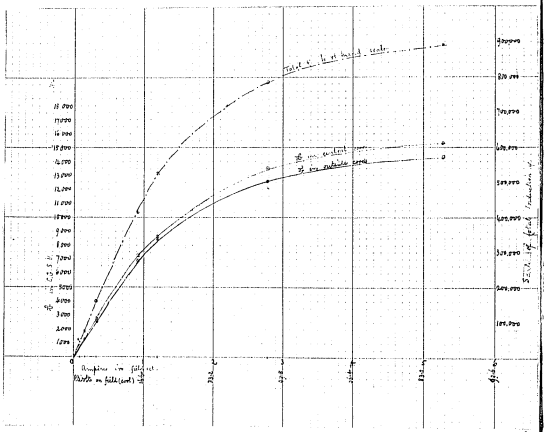
"Diam." of centre core 8.6 area 58.09

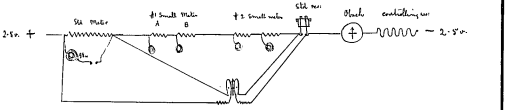
" " outside " 6.3 " 31.17 × 2 = 62.34

Turns on outside cores 113 × 110 = 12,65

" " inside " about 800 085

19,900 × 1.257 = 2390





$\frac{23}{\frac{1}{9}} \times 0.03 = 0.27$

∴ 041.0027 Lw.

$\frac{0.009833 \times 2735.5}{2716} = 0.009942$

$\frac{0.009833 \times 2753.5}{2716} = 0.009997$

$\frac{0.009833 \times 2728.5}{2716} = 0.009906$

$\frac{0.009833 \times 2741.5}{2716} = 0.009953$

Magnetic Characteristic of Rock Drill Apparatus. Febry 28th 90.

The machine is in the condition represented on page 158 with the polar heads shown in red ink. The following observations were taken with 5 turns of twist wire layed closely round the middle core the center of the band being abt 12 from the yoke and being about 3 wide. The current was reversed through the cores, so that a single induction = ½ the observed induction. The three limbs were in series the two outside poles of same name and the inside of opposite name.

Obs. No.	Check Amp	Amperes	No. of Rev. Shunt	Mean	Res. in cir.	Total res. of Galvo. cir.	φ	φ	½ on outside core	½ on outside cores	M.M.F.
1	1.014	5.224	3	107	100,000	105250	8.478×10^{-8}	5.92×10^{-8}	1.576×10^{-6}	1.431×10^{-6}	1.262×10^{-6}
2	0.584	2.78	3	94	.		7.408	7.82	1.35	1.26	6.612×10^{4}
3	0.236	1.20	5	63	.		4.994	5.26	0.598×10^{-8}	8.612×10^{-8}	2.57
4	0.179	0.91	5	51.2	.		4.057	4.27	7.35	6.85	2.18
5	–		3	174	25000	30250	1.379×10^{-7}	4.17	7.18	6.69	
6	0.065	0.33	3	66.5	"		5.269×10^{-8}	1.59	2.74	2.55	7.89×10^{4}
7	0.032	0.163	5	30.6	"		2.425	0.734	1.26	1.18	
8	12.* ×	0.1603	16	177	0	5250	1.102×10^{-8}	0.736	1.27	1.18	3.85
9	7.356	0.0991	2	116.5	0		9.23×10^{-9}	0.408	8.35×10^{-8}	7.78×10^{-8}	2.37
10	1.431	note C.C. @ 21°C	8	754	–	0.4475^{-8}	5.975×10^{-8}				

* Standard galvo.

Res. of the three core windings in series 16.6 ω coil.

Test of meters before experimental use.

Standard 0.1 – 100 ω meter made at Laboratory 1888.

Found one clip on strip indecent, readjusted it.

Res. of shunt by ballistic actuate galvo. diff. res. both coils 743 Ω – $\frac{1000}{1000}$ no. 5. T.B. 23°C T.G. 23°C. = 2716.5 ω each set of coils.

5 volt dynamo current. Connections as shown opposite

Standard copy of 0.1 legal ω correct at 14°C. Temp. of Std 23° = 0.10037

27 ω added to Std for balance = $\frac{1.00027 \times 10^{-1} \times 27\,16.5}{2743}$ = 0.09983 ω = 0.8°C

easily adjustable to 1%

Res. of spool 98.05 ω with its connections @ 21°C.

Current 1.5 amps through main cct.

100,000 ω in cct. with galvo. gives 270 divs ∴ $\frac{270 \times 102,720}{2720}$ = 10,000 divs

approx. would be obtained with one res. alone.

#1 Small meter by Bergmann compared with 0.01 ω copy = 0.009831 @ 23.5°

A side 27 ω added to strip = 0.009942 ω

B " 37 ω " " " = 0.009997 ω

#2 " " " A " 12 ω " " " = 0.009906 ω

B " 25 ω " " " = 0.009953 ω

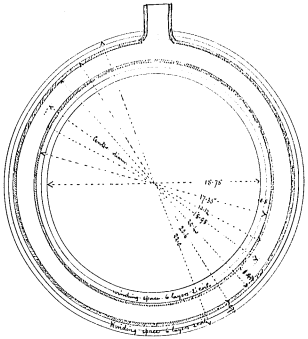
Spools #1 " " " A " 8.045 ω @ 22°C

B " 8.125 ω "

" #2 " " " A " 8.075 ω "

B " 8.075 ω "

Section scale ½ of ring in plane through centre of tube and perpendicular to axis of ring



If O be the centre (of symmetry) of the
X and Y the rectangular axes,
R the int. radius of the ring
a " " axis of tube
Then y the coordinate of any point on the
circumference is $R \pm \sqrt{\rho^2 - x^2}$ where $\rho = R - r$
The volume of the tube on any lamina
comprised between planes through x and x+
$\int dx \, 2\pi \, R + \sqrt{\rho^2 - x^2}$
$4\pi R + \sqrt{\rho^2 - x^2} \, dx$
and this must be integrated from x = ±ρ to
$u = R \int_{-\rho}^{\rho} \sqrt{\rho^2 - x^2} \, dx$

$= \frac{4\pi R}{2} \pi \rho^2 = 2\pi^2 R \rho^2$

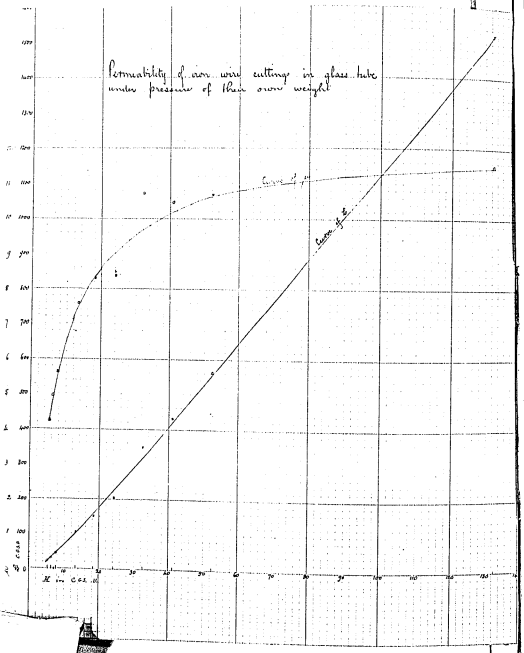
$R = 0.449$
$2\pi^2 R = 187.325$
$\therefore \rho^2 = \frac{100}{187.325} = 0.5349814$

$\rho = 0.7415$

$2\rho = 1.4830$
$2\rho + 2t = 1.6250$
0.142
$t = 0.071$

Let h = cylinder area
a = area of inside tube
$\phi = a\mathfrak{t} + (h-a)h$
when $\phi = Ah = n\,ah$
$\therefore \phi = a\mathfrak{t} + (n-1)ah$
$= n\rho h + (n-1)ah$
$= ah(n + n - 1)$
$\mathfrak{t} = \frac{h(2n-1)}{a}$

$\mu = \mu - (n-1)$
$= 5.20$



1164

Particulars of a Faraday Ring of glass tube for investigating the permeability of liquids and powders.

Ext. diam. of anchor ring of glass tube 20.6
Int. " " " " 17.35
Ext. " " glass tube itself 1.625
Int. " " " " 1.480 by calculation from measurement

This anchor ring has a neck for filling it. The neck occupies an angular distance of about . Two coils each of three layers or six layers in all are wound on the ring. The first layer has 516 turns
" 2nd " " 488 " 25
" 3rd " " 476 " 24
1480 . in first coil
" 4th " " 460 " 24
" 5th " " 456 " 23
" 6th " " 441 " 22
1357 . in second coil.

Res. of primary coil 4.28 ω @ 23°C
" secondary " 5.16 ω @ 23°C

Contents of tube 103 c.c.

The tube was filled to the base of the neck with very short lengths of soft iron wire 0.06 diam. the lengths being about 0.1, or a little less. The weight of these cuttings was 4.67 grammes. The following observations were then made upon the permeability. Current measured.

No. of Obs.	Deflect. obtd.	Current amp.	No. of Bunsen elements	Mean	Res. in cct.	Total res. of galv. cct.	q	φ	$\mathcal{L}$	M.M.S.	μ	Mean μ	Corr. μ
1	12°.45′.0	0.1706	3	31.8	0	5.280	3.528×10^{-3}	1.259×10^{-3}	2.90×10^{-3}	5.32×10^{-3}	5.145	2.24	4.25
2	14°.45′.0	0.1985	3	41.5			3.90	1.785	3.81×10⁻³	6.19	6.16	2.97	4.96
3	18°.20′.0	0.2496	3	65.3			5.32	2.793	5.96	7.79	6.83	3.39	5.63
4	28°.55′.0 / 29°.15′.0	0.4156 / 0.4.4	2 / 2	114.4			1.172×10^{-2}	6.154	1.313×10^{-2}	1.30×10^{-2} / 1.37	9.22 / 9.68	8.79	9.79
5	0.115	0.584	5	189.3			1.580	8.096	1.725	1.62	9.48	1.500	8.28
6	0.152	0.772	4 / 5	216.4 / 255.5	25000	30.250	2.096	1.095×10^{-1}	2.336	2.41	9.69	9.59 / 3.52	8.39
7	0.205	1.021	2	73.5			5.98	1.809	3.860	3.25	11.97	3.41	10.47
8	0.260	1.320	2	91.25			7.23	2.268	4.797	4.12	11.68	4.31	10.45
9	0.332	1.686	6	118.7			4.66	2.923	6.237	5.26	11.86	5.41	10.66
10	0.835	4.24	1 / 2	327 / 176	50000 / 50000	55.250 / 55.250	2.66×10^{-2} / 1.33×10^{-2}	8.048 / 7.620	1.627×10^{-1}	1.323×10^{-1} / 1.7[illegible]	12.93 / 12.44	12.70	11.50
11	0.525	4.21	1 / 2	50 / 320		5.250	2.44×10^{-2} / 2.61×10^{-2}	1.368×10^{-1} / 1.371×10^{-1}	2.276×10^{-1} / 2.925×10^{-1}	1.314	2.205		4.001
12	0.260	1.32	2	97			7.59	4.141×10^{-2}	8.236×10^{-2}	4.12×10^{-2}	2.14		
13													

* Standard Galv.

1 C.C. Phos. 0.4175 ℔ gives 73.6 divs. $= 5.98\times10^{-5}$ ℔ for 73.5 divs
$= 8.136\times10^{-4}$ ℔ " 1 div.

$2714 \times 1.727 = 4687 = 4.687\times10^{3}$ coeff of ξ

$\frac{1480}{59.63} = 24.81 \times 1.257 = 31.2$

Investigation of the economy of supplying the Pearl St. district N.Y. by a main feeder from Canal St.

Let w be the activity in all the lamps at full load (watts) near lamps

f - - - - the feeder " " "

h - - - - house wire mains - - - "

d - - - - dynamo armatures - - - "

m - - - - overcoming friction - - - -

β - - - fractional loss of activity of circuit lost in feeder at full load

n - - - fractional load at any time in lamps in terms of full load

r - - - average fractional load such that if continued steadily the annual losses and transmission would equal the actual the sum of the actual losses and transmission each to each.

y - - - number of seconds in a year.

c - - - cost of a watts per year. \$

$r_1\ r_2\ r_f\ r_d$ - - resistance of the lamps, mains, feeder, & armatures in equivalent lamp circuit

K - a constant of investment in feeder. copper.

φ - - function - - - - mon. + fitting.

Then $f = \beta\,(w + d + f + h) = \beta\,(W - m)$ Watts (1)

or $W = \beta\,(W - m) + m + w + d + h$ Watts (2)

or $W(1-\beta) = m\,(1-\beta) + d + h + w$ " (3)

and $W_n = mn + n^2\{\beta\,(W-m) + d + h\beta + nw$ " (4)

$J = W_n y = vy\,[m + w + v\{\beta\,(W-m) + d + h\beta\}]$ Joules. (5)

$Jc = cvy\,[m + w + v\{\beta\,(W-m) + d + h\beta\}]$ \$ (6)

Also $r_f = \beta\,(r_1 + r_f + r_2 + r_d)$

$$r_f(1-\beta) = \beta\,(r_1 + r_2 + r_d)$$

$$r_f = \frac{\beta}{1-\beta}\,(r_1 + r_2 + r_d)$$

$$c_f = \frac{K_f}{r_f} + \varphi(r_f)$$

$$= \frac{K_f(1-\beta)}{r_d\beta} + \varphi(\beta)$$

annual cost $q c_f = q\left\{\frac{K(1-\beta)}{\beta} + \varphi(\beta)\right\}$ \$

Total annual cost $C = cvy\,[m + w + v\{\beta\,(W-m) + d + h\beta\}] + q\left\{\frac{K(1-\beta)}{\beta} + \varphi(\beta)\right\}$.

$$\frac{dC}{d\beta} = cv^2y\,(W-m) + q\varphi'(\beta) - \frac{qK}{\beta^2}$$

$$\therefore \frac{qK}{\beta^2} = cv^2y\,(W-m) + q\varphi'(\beta)$$

Let $q\varphi'(\beta) = s$ since $\varphi(\beta)$ will generally be a linear function

$$\beta^2 = \frac{qK}{cv^2y\,(W-m) + s}$$

$$\beta = \sqrt{\frac{qK}{cv^2y\,(W-m) + s}}$$

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